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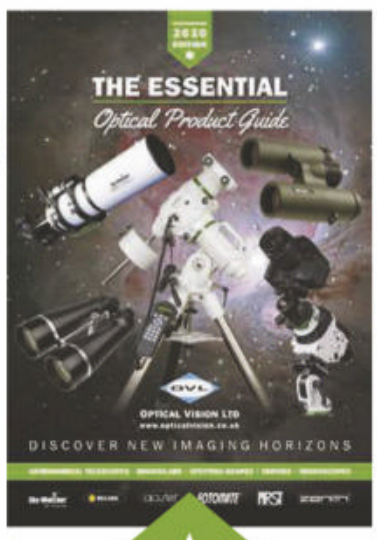

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Welcome

Celebrate the dark nights with us under the stars!

On Christmas Day many budding stargazers will discover a new telescope under the tree waiting to be unwrapped. Yet telescopes and astronomy both reward experience, and excitement can turn to disappointment when it's taken out under the stars for the first time if expectations are dashed. However, our first-time telescope tour on **page 36** this month will get your stargazing journey off to the best possible start. Lifelong astronomer and author Stuart Atkinson provides six simple targets to train a new telescope on, which will really show what it is capable of and whet your appetite for the months ahead!

And there's much more to train a telescope on over the winter, as you'll discover on **page 70**. Here Katrin Raynor-Evans looks ahead to the constellations that will be a highlight of the night skies for the rest of the season, giving you plenty to track down over the long, dark nights.

Once you've got to grips with your new telescope, you may be looking for some new observing equipment. In which case our expert guide to sourcing and buying second-hand kit is a must-read. On **page 64** Charlotte Daniels considers the questions a buyer should ask when looking for pre-owned kit including telescopes, mounts and accessories, helping you steer clear of common pitfalls when you make that deal.

There's much to look forward to in the New Year in terms of space exploration too, and on **page 29** we preview the biggest missions that are set to launch in 2021. These include the first ever helicopter flight on another planet, and the planned first launch of the NASA rocket that will take humans back to the Moon, the mighty Space Launch System.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 21 January.

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16-PAGE CENTRE PULLOUT

COVER MAIN IMAGE: HIFUMIYO/FOLIO. THIS PAGE: ALLEXXANDAR/ISTOCK/GETTY IMAGES, NASA/MSFC, NASA, @THESHED_PHOTOSTUDIO, CHART BY PETE LAWRENCE, CHARLOTTE DANIELS, NASA, BBC

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

This month's contributors

Charlotte Daniels

Astrophotographer

"When I started out in astronomy I picked up so many tips from people selling kit; buying second-hand is a great way to help make informed purchases." **Charlotte advises on buying second-hand,** page 64

Ben Evans

Spaceflight writer

"The year 2021 promises new rockets, new missions of discovery and new opportunities in space. As we return to the Moon, I'm getting excited by a bright future". **Ben looks forward to 2021's space missions,** page 29

Katrin Raynor-Evans

Astronomy writer

"I loved writing this piece for the complete novice; I wanted to share my enthusiasm for my favourite observing season!" **Katrin introduces the best winter constellation targets to view,** page 70

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/FWR8NA9/** to access this month's selection of exclusive Bonus Content

JANUARY HIGHLIGHTS

Interview: NASA astronaut Terry Virts

Colonel Virts discusses life in zero-G, what the stars look like on a spacewalk and the prospect of humans on Mars.

The Sky at Night: Life Beyond Venus

The team take closer look at this year's discovery of phosphine on Venus and discover the next steps in the search for signs of life.

Download observing guides and charts

Access planet observing forms, binocular and deep-sky tours and our guide to Southern Hemisphere stargazing.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

SECRET IN THE SHADOWS

Luminous rays and dark shadows paint a cosmic chiaroscuro

HUBBLE SPACE TELESCOPE, 23 NOVEMBER 2020

Bright beams of light pour from IC 5063, a galaxy 156 million lightyears away in the southern constellation of Indus, in this new image from the Hubble Space Telescope. Shooting out more than 36,000 lightyears into space, the rays emanate from the galaxy's core, where an active supermassive black hole resides, greedily feasting on the infalling material that surrounds it. In the process, it superheats nearby gases, producing the powerful rays of bright light that we see here.

The accompanying dark rays, however, are more of a mystery. One exciting theory is that they reveal the presence of a circle of dust around the black hole at the galaxy's heart – a circle that's warping and full of holes like Swiss cheese – where the light is able to flood through. It's the first time the phenomenon has been captured and it only came to light thanks to the skills of amateur image processor Judy Schmidt.

MORE **ONLINE**

A gallery of these and more stunning space images

NASA/ESA ND W.P. MAKSYM (CFA)

△ Spotlight on the bulge

VICTOR M BLANCO TELESCOPE, 27 OCTOBER 2020

They looked at an area of sky 1,000 times as large as the full Moon, surveyed 250 million stars, captured 450,000 individual images, and profiled the chemistry of 70,000 stars. In the biggest investigation yet into the central bulge of our Milky Way, a 20-plus strong team of international researchers used data from the Dark Energy Camera (DECam) on Chile's Victor M Blanco 4m Telescope to conclude that nearly all the stars in our Galaxy's bulge formed in a single burst of star formation more than 10 billion years ago.

Strange skull ▷

VERY LARGE TELESCOPE, 30 OCTOBER 2020

Eerie in more ways than one, NGC 246, nicknamed the Skull, is the only known planetary nebula with a triple stellar system. Its white dwarf is one of a binary pair visible in the centre, which are both orbited by an unseen third companion, a red dwarf.

CTIO/NOIRLAB/DOE/NSF/AURA/STSCI/W. CLARKSON (UM-DEARBORN)/C. JOHNSON (STSCI) AND M. RICH (UCLA)/E.SLAWIK, ESO, ESA/HUBBLE & NASA/A. ADAMO ET AL/CC BY 4.0, GBT/NSF/NAOJ/ HSC-SSP/ESA/XMM-NEWTON/XXL SURVEY CONSORTIUM

Weird and wonderful ▷

HUBBLE SPACE TELESCOPE, 26 OCTOBER 2020

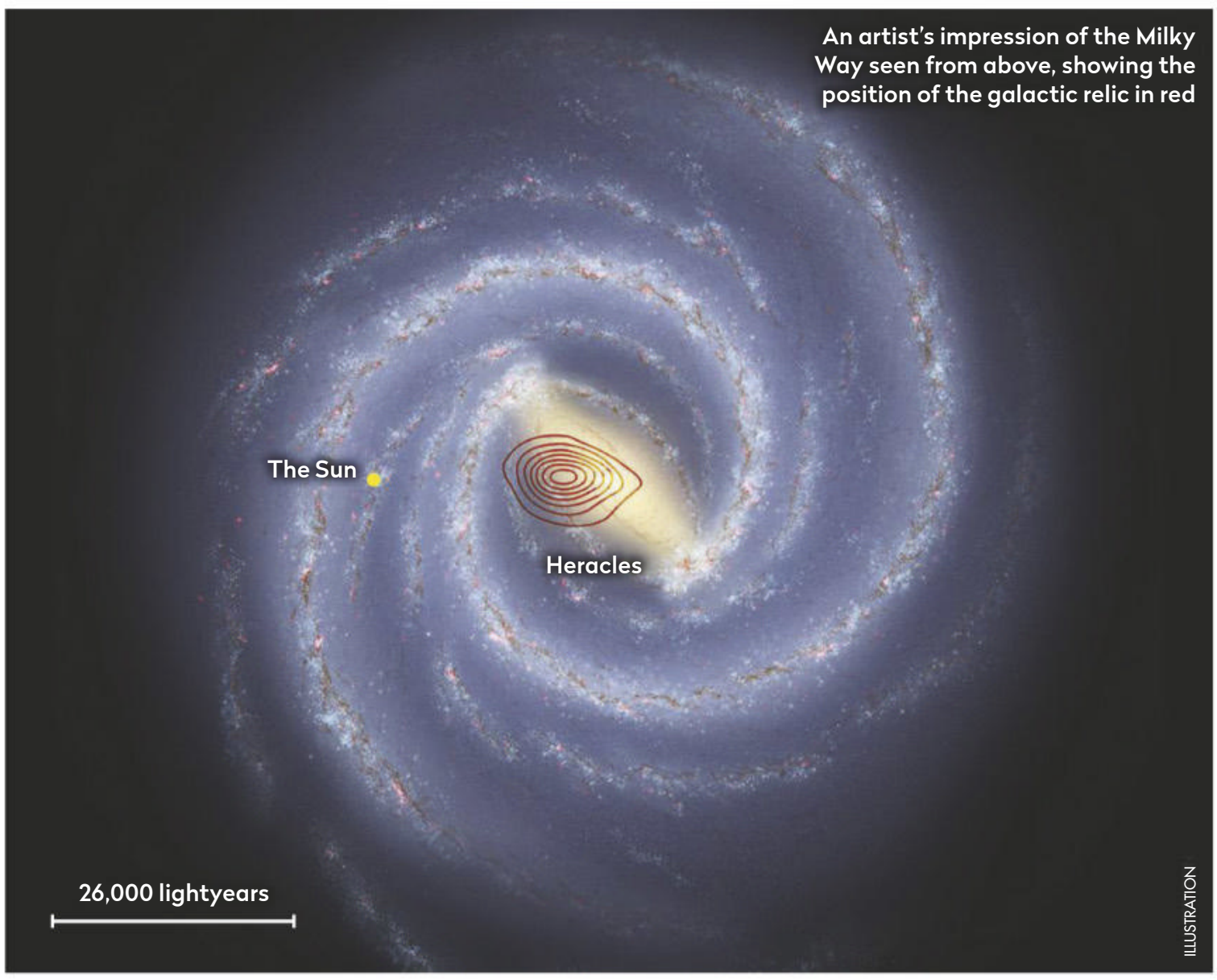
The stunning survivor of a galactic pile-up, NGC 34 is what remains after two spiral galaxies met head-on several million years ago. Their merger has created this perplexing, ghostly form, its core glowing with frenzied stellar formation triggered by the union. Still officially a spiral galaxy for now, NGC 34 will eventually join the ranks of the 'peculiar' galaxies, the five per cent of star systems that don't conform to regular shapes and sizes.

▽ When clusters collide

SUBARU TELESCOPE, XMM-NEWTON SATELLITE AND GREEN BANK TELESCOPE, 12 NOVEMBER 2020

In a composite image of visible, radio, and X-ray light, we see a pair of galaxy clusters colliding in a clash so violent it released enough energy to heat the surrounding gas to 400 million °C. The Subaru image has overlaid colours of dark matter (blue), hot gas (green) and high-pressure gas (red).

BULLETIN



An artist's impression of the Milky Way seen from above, showing the position of the galactic relic in red

DANNY HORTA-DARRINGTON (LIVERPOOL JOHN MOORES UNIVERSITY) NASA/JPL-CALTECH AND THE SDSS, ESA/STFC/RAL SPACE/UCL/EUROPLANET-SCIENCE OFFICE, BACC/HANDOUT VIA XINHUA

ILLUSTRATION

Galactic relic discovered in Milky Way

Remains found from a galaxy that merged with ours billions of years ago

A 'fossil galaxy' has been identified hiding in the heart of the Milky Way thanks to a campaign that's observing over half a million stars. The galactic relic, which astronomers dubbed Heracles, was once a separate galaxy but collided and merged with our own Galaxy around 10 billion years ago.

Heracles was discovered using the Apache Point Observatory Galactic Evolution Experiment (APOGEE), which has been tracking stars across the Milky Way. As the instrument looks at infrared light it's able to pick out stars in the dusty galactic core that are usually obscured from view.

"Of the tens of thousands of stars we looked at, a few hundred had strikingly different chemical compositions and velocities," says Danny Horta, who led the study. "These stars are so different that they could only have come from another galaxy. By studying them in detail, we could trace out the precise location and history of this fossil galaxy."

The new study estimates that around a third of the stars in the Milky Way's halo originated in Heracles, meaning the event which merged the two would have been a major milestone in our Galaxy's history. Its discovery will help astronomers work out how our Milky Way grew and evolved into what we know today.

"As our cosmic home, the Milky Way is already special to us, but this ancient galaxy buried within makes it even more special," says Ricardo Schiavon from Liverpool John Moores University, a member of the research team. "APOGEE lets us pierce through the dust and see deeper into the heart of the Milky Way than ever before."

https://sdss.org

Comment

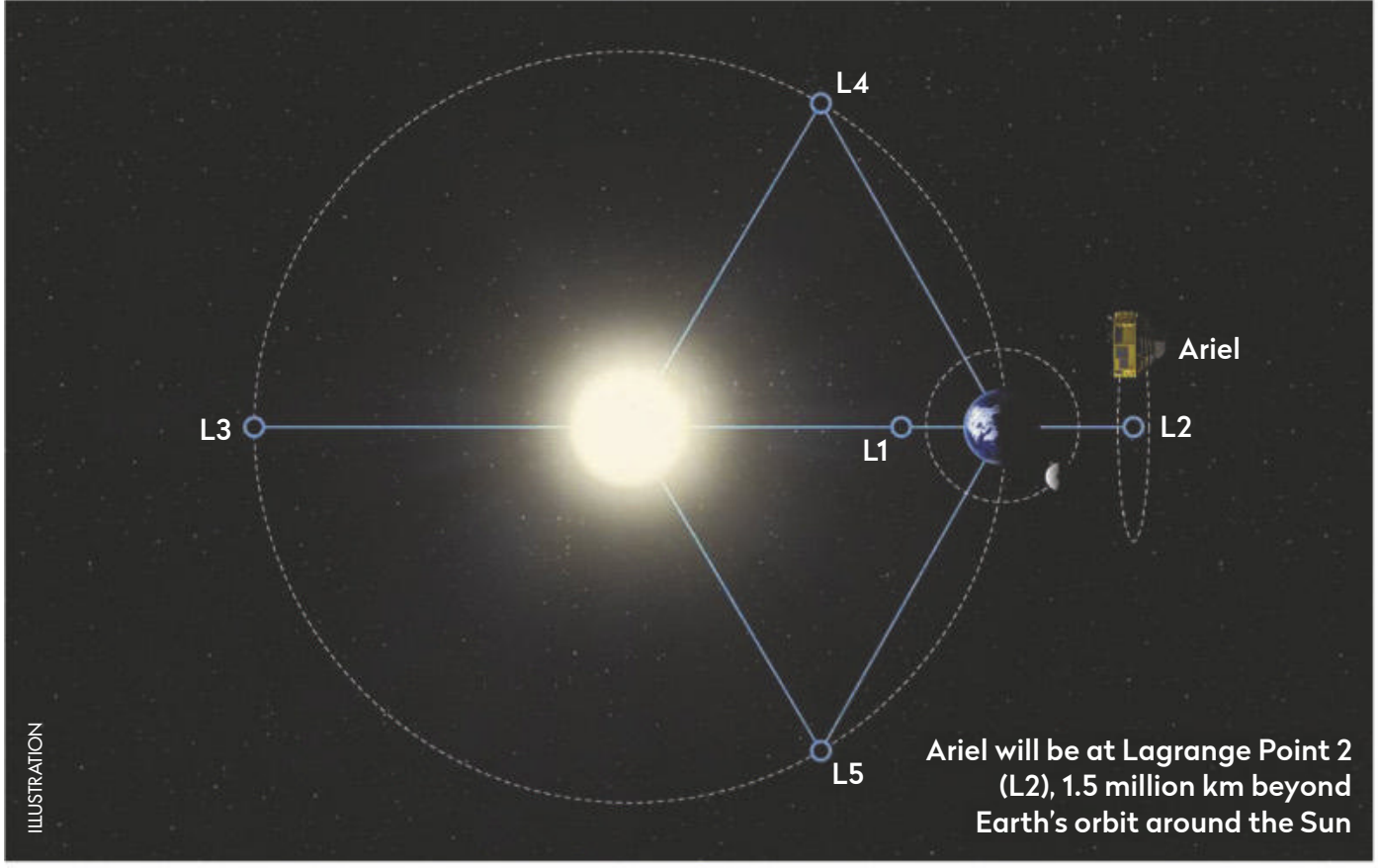
by Chris Lintott

For decades, the fact that it's hard to get a good overall view of a galaxy when you live in it meant that we often knew more about neighbouring systems.

Surveys like APOGEE and the Australian GALAH are changing that, using modern instruments to provide a library of stellar spectra to be mined. ESA's Gaia satellite is important too, mapping the positions and movements of the nearest billion stars.

By the time you read this, the Gaia team will have completed the third major data release in its history. Exploring the resulting new map – along with data from ground-based scopes – will give more surprises; expect to hear more about the Milky Way soon!

Chris Lintott co-presents *The Sky at Night*



Ariel will be at Lagrange Point 2 (L2), 1.5 million km beyond Earth's orbit around the Sun

UK to lead exoplanet mission

The spacecraft will look at the atmospheres of distant worlds

A UK-led telescope which will explore atmospheres around planets beyond our Solar System was green-lit in November 2020 and is now set to launch in 2029.

The Atmospheric Remote-sensing Infrared Exoplanet Large-Survey (Ariel) will observe the starlight shining through atmospheres of 1,000 exoplanets, which astronomers will then use to look for the signatures of chemical compounds such as water vapour, carbon dioxide and methane.

"We're the first generation capable of studying planets around other stars," says Giovanna Tinetti, principal investigator for Ariel from University College London. "Ariel will seize this opportunity and reveal the nature and history of hundreds of diverse worlds in our Galaxy."
https://arielmission.space

China's sample-return mission lands on Moon

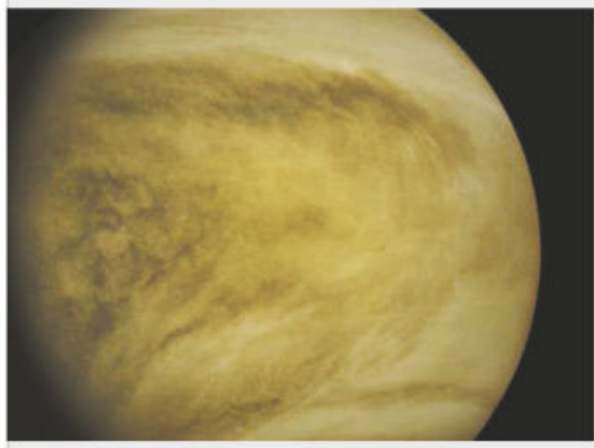
Mission controllers in Beijing monitor the progress of Chang'e-5

Moonrocks could soon be bound for Earth once again, after China's Chang'e-5 sample-return mission successfully landed on the Moon on 1 December. The spacecraft is expected to return to Earth with a lunar sample in mid-December – the first such return since the Soviet Luna 24 mission in 1976.

At the time of writing, Chang'e-5 was beginning its attempt to drill into the lunar surface in the Mons Rümker region of Oceanus Procellarum – a volcanic peak that is much younger than the surfaces visited by the Apollo missions. By the time you read this, it's hoped the mission will have collected 2kg of lunar material and transferred it to a return capsule, which is due back on Earth around 15–16 December.

The mission is China's next step in its Chang'e programme of lunar exploration, which has already seen the first landing on the Moon's far side. It will hopefully pave the way for a future human landing
www.cnsa.gov.cn/english

NEWS IN BRIEF



Venus holding its water

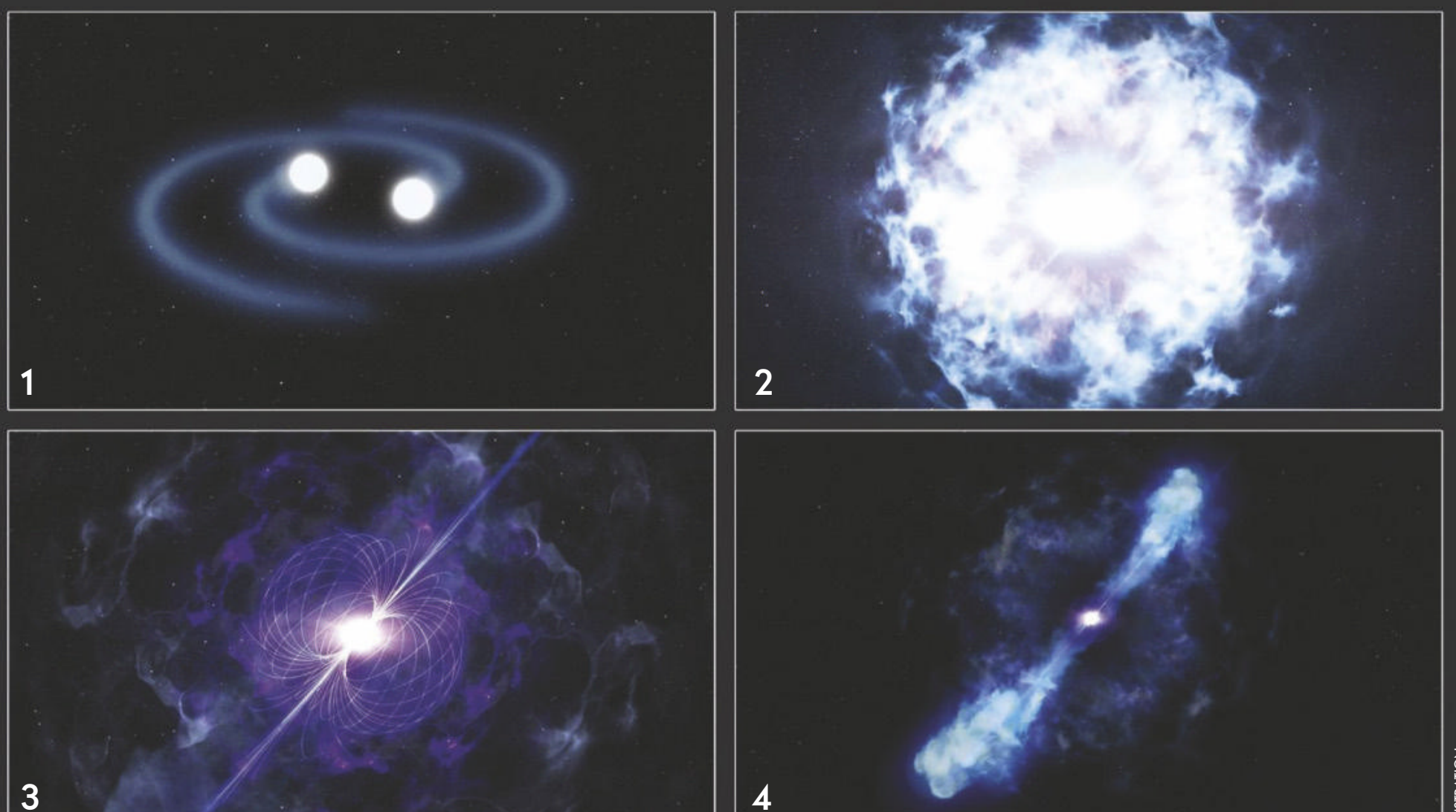
Venus has lost much less of its water to space than previously thought, according to a recently published thesis. Moa Persson used ESA's Venus Express to measure how much water was being swept away by the solar wind and found that not only were the levels unexpectedly low, they varied with the solar cycle.

Blind astronomy

A project to help blind people 'see' the Universe has received an award from the Falling Walls Foundation. The Tactile Universe, led by vision-impaired astronomer Nicolas Bonne at the University of Portsmouth, uses 3D-printed models of galaxies to allow the blind community to understand their shape.

Meteorite reveals inner Mars

Crystals of young material only a few hundred million years old have been found inside a Martian meteorite. It's thought the crystals originated in the planet's interior and will now give geologists a way to study this normally inaccessible region.



NASA/ESA AND D. PLAYER (STSCI), NASA/ESA/W. FONG (NORTHWESTERN UNIVERSITY) AND T. LASKAR (UNIVERSITY OF BATH/UK), ROGER RESSMEYER/CORBIS/VCG VIA GETTY IMAGES ILLUSTRATION

▲ **The gamma-ray burst could be the result of a neutron star merger (1-4), which creates a brightly glowing magnetar**

Stellar explosion's afterglow burns brighter

The distant burst emitted 10 times more infrared energy than anticipated

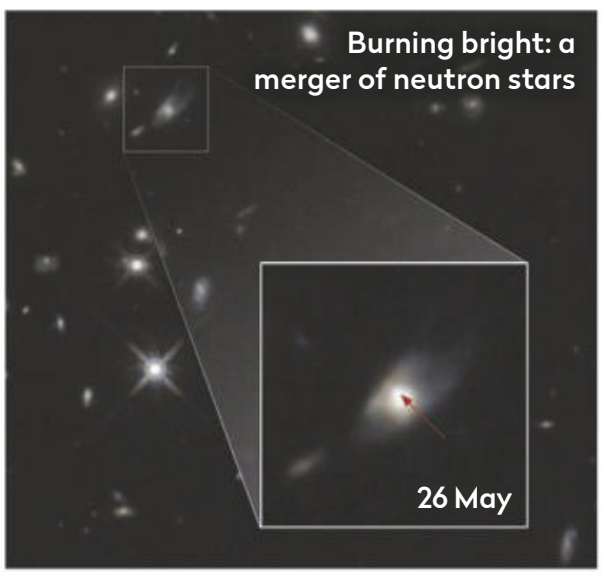
A short gamma-ray burst, which released more energy in half a second than the Sun will in its 10-billion-year lifespan, could be brighter than first thought, as new measurements pinpoint its origin to a galaxy further away than anticipated.

The burst was first seen in May 2020. As soon as word of the explosion spread, astronomers rushed to observe the area of sky it had occurred in and were able to get time on the Hubble Space Telescope just three days after the flash. These follow-up images revealed something very surprising – the infrared afterglow was 10 times brighter than anticipated.

"These observations do not fit traditional explanations for short gamma-ray bursts," said Northwestern University's Wen-fai Fong, who led the study. "Given what we know about the radio and X-rays from this blast, it just doesn't match up. The near-infrared emission that we're finding with Hubble is way too bright."

The team needed to know how bright the blast was, so they measured how far away the explosion's host galaxy is with Hawaii's WM Keck Observatory.

"Distances are important in calculating the burst's true brightness, as opposed to its apparent brightness seen from Earth," says Fong. "Just as the brightness of a light bulb when it reaches your eye depends on both its luminosity and its distance from you, a burst could be really bright because either it is intrinsically luminous and distant, or not as luminous but much closer to us. We found it was more energetic than we first thought."



The observations found the blast was further away, and so brighter, than expected, leading to questions over what had caused it. Most bursts like it are believed to originate from merging neutron stars, and a theory is that in this case the resulting object, a magnetar, had a strong magnetic field. This field could eject material out of the blast with enormous energies, causing it to glow brighter than normal. **https://keckobservatory.org**

Arecibo's dish to be dismantled

The Arecibo Radio Observatory, which has helped astronomers look at the deepest depths of the Universe for 57 years, is no more. On 1 December, its 820-tonne central platform collapsed onto the dish 135m below.

The accident came just weeks after the decision was taken to decommission the telescope, after two of its suspension cables snapped. Though the support system had been inspected regularly (as technician Luis Heredia is doing here in 1989), the collapse was caused when the tops of its support towers broke off.

The 305m-diameter telescope, built into the hills of Puerto Rico, has long been a popular icon of astronomy, featuring in the James Bond film *Goldeneye* (1995) and *Contact* (1997) with Jodie Foster. It will be much missed.

NEWS IN BRIEF

Rocket relic recaptured

Earth has temporarily recaptured what appears to be the booster rocket from the Surveyor 2 mission, which failed to land on the Moon in 1966. The booster had been orbiting the Sun ever since, until it came close enough to Earth on 8 November 2020 to be captured by Earth's gravity – though it will escape again after a few months.

Cosmic flashes come in all sizes

The first fast radio burst ever seen in our Galaxy, spotted on April 2020, was followed by two smaller bursts a few months later, according to a recently released study. The explosions are much weaker than any previously observed, suggesting the strength of these mysterious blasts could be astonishingly diverse.

Mixed up Milky Way

A study of the Milky Way's oldest stars has found many within the inner Galaxy, forcing astronomers to re-evaluate how our cosmic home formed. Current theories predict old stars should only be in the Galactic halo, but the report found one in ten orbited along the disc like our Sun does.

GENERAL DYNAMICS/SDASM, NASA/SPACE X, JUSTICE WAINWRIGHT, NASA/KIM SHIFLETT

BULLETIN

SpaceX carries first official crew to the ISS

NASA begins new era of operations with commercial crew launches

Transported by SpaceX: (from left) astronauts Michael Hopkins, Victor Glover and Shannon Walker

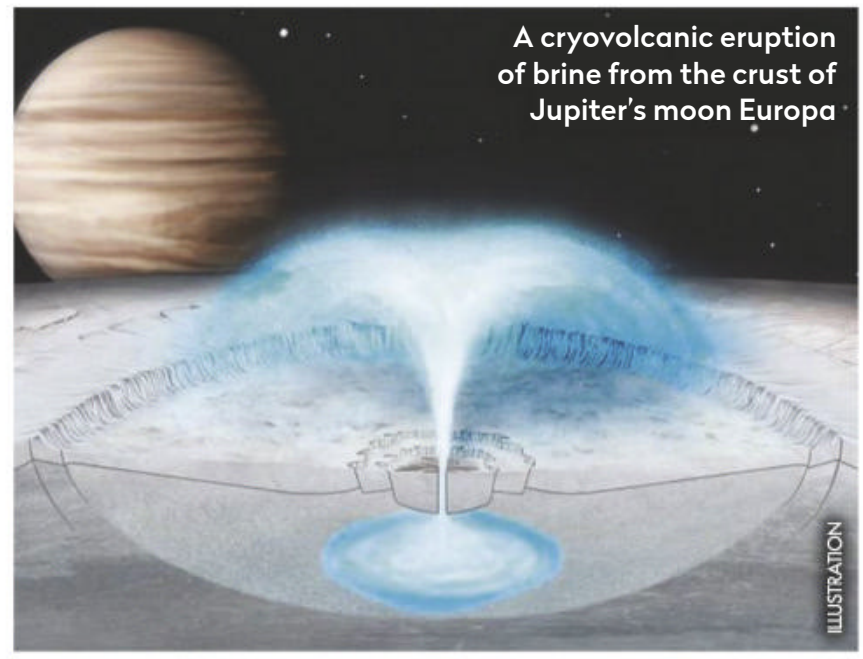
The first ever operational crew to travel to the International Space Station (ISS) on board a commercially built spacecraft arrived at the station on 16 November 2020.

The mission, Crew-1, marks the first time NASA has been able to launch its astronauts from American soil since the Space Shuttle ceased operations in 2011.

The astronauts travelled on-board 'Resilience', one of SpaceX's reusable Crew Dragon capsules, which were cleared for human use by NASA after a successful flight at the beginning of 2020. Though the capsule can carry a crew of seven, Crew-1 only consisted of four people: NASA astronauts Michael Hopkins, Victor Glover, Shannon Walker and Japan Aerospace Exploration Agency (JAXA) astronaut Soichi Noguchi. "SpaceX and NASA, congratulations. This is a new era of operational flight to the International Space Station from the Florida coast," said Hopkins shortly after docking with the ISS.

www.spacex.com

Europa's plumes could come from its crust



A cryovolcanic eruption of brine from the crust of Jupiter's moon Europa

ILLUSTRATION

The water plumes seen venting from the surface of Saturn's icy moon Europa could be coming from its crust, rather than from a subsurface ocean. A new set of simulations proposes that brine could be migrating throughout the moon's crust. Using the 29km-wide Manannán crater as an example, these models found that the water could get trapped by certain geological features causing the pressure to build until the water erupts, shooting high above the surface.

The icy moons have been of great interest in recent years as they're considered one of the most likely spots to find life beyond Earth. These plumes offer future missions – such as the upcoming Europa Clipper – a way to study this water without having to drill into the moon's surface.

"Understanding where these water plumes are coming from is very important for knowing whether future Europa explorers could have a chance to actually detect life from space without probing Europa's ocean," says Gregor Steinbrügge from Stanford University, who took part in the study.

https://europa.nasa.gov/

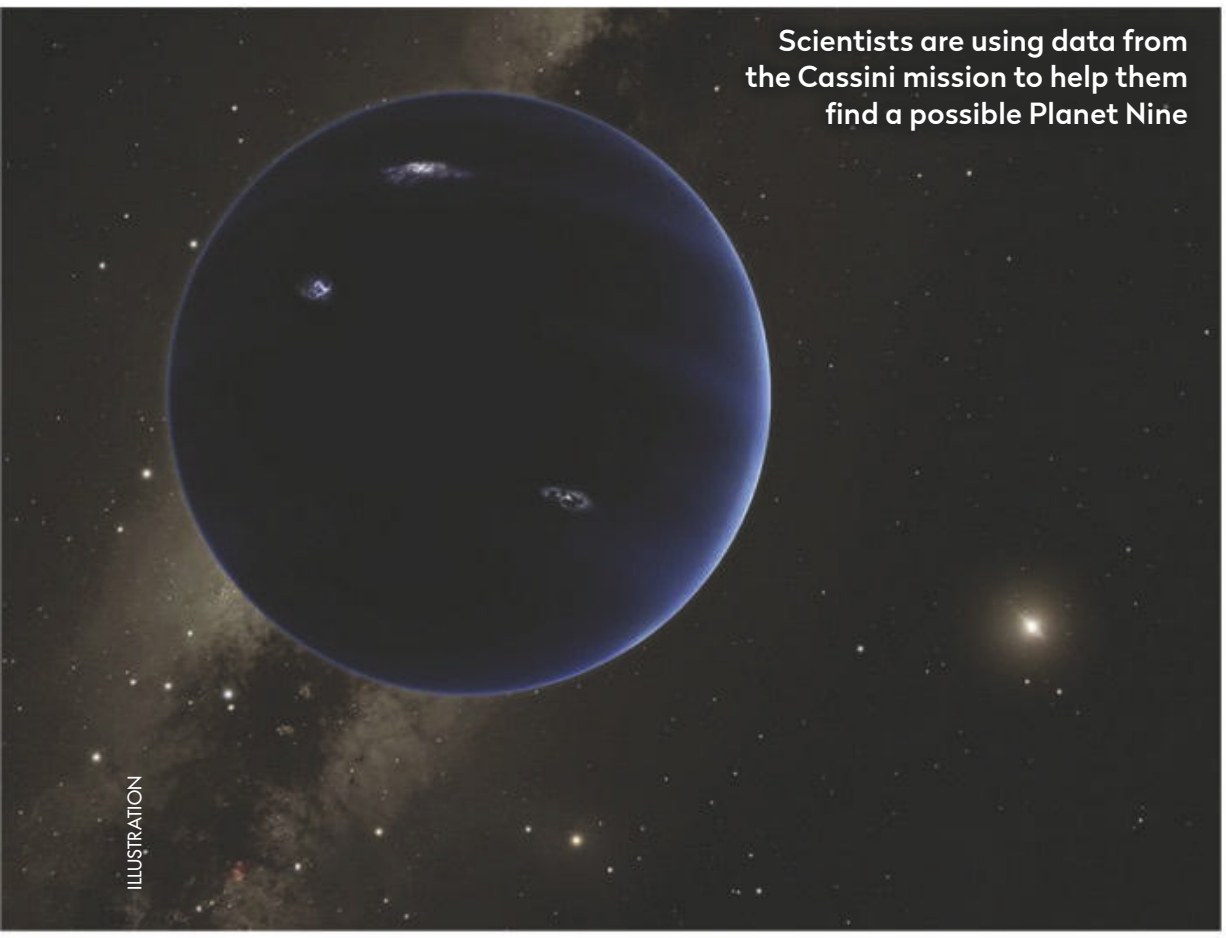
Preparations for Artemis-1 launch are stacking up

The first part of the Space Launch System (SLS), NASA's new heavy launch rocket, was stacked onto the mobile launcher at the end of November, in preparation for its inaugural test flight next year. Its twin solid rocket boosters are here shown being put together inside the Vehicle Assembly Building at Kennedy Space Center. Once constructed, the SLS will stand 111m high – taller than the Statue of Liberty – and generate 15 per cent more thrust at take-off than the Saturn V rocket, which launched the Apollo missions. The SLS will be used as part of the Artemis-1 mission, the first test of both NASA's new launch vehicle and the Orion crew capsule, which the agency plans to use to return humans to the surface of the Moon.

▸ Read more about the Artemis-1 mission in our feature on page 29

Our experts examine the hottest new research

CUTTING EDGE



Scientists are using data from the Cassini mission to help them find a possible Planet Nine

ILLUSTRATION CALTECH/R. HURT (IPAC), NASA/ESA AND G. BACON (STSCI)

Weighing the Kuiper Belt

The measurement was made with an unusual instrument – the Cassini spacecraft observing Saturn

Far away in the gloomy, distant suburbs of the outer Solar System, beyond the orbit of Neptune, lies a whole swarm of small, icy bodies. These trans-Neptunian objects (TNOs) mostly orbit at a distance of between about 30 and 50 astronomical units (AU) from the Sun – where 1 AU is the distance between the Sun and Earth. They make up the Kuiper Belt, a diffuse disc some 20 times wider than the asteroid belt and around 100 times more massive.

As more and more TNOs have been discovered, something very strange has been noticed; one group of TNOs cluster together and all make their closest approach to the Sun in the same sector. In 2016, an unseen ninth planet was proposed to explain these curious anomalies – a super-Earth orbiting at over 400 AU, whose gravity is shepherding these Kuiper Belt objects. Attempts to locate this elusive potential planet have so far failed, but what would really help pin down any gravitational interactions from Planet Nine is a much clearer understanding of the masses of these TNOs. So how do you weigh the Kuiper Belt from over 6 billion km away?

Andrea Di Ruscio, at the Sapienza University of Rome, and his colleagues have used an ingenious method to tackle this. They used data from the Cassini probe to calculate the position of Saturn extremely accurately, and then used perturbations to this orbit to infer the cumulative mass of the TNOs.

With an intricate looping tour around Saturn and its moons for over 13 years, Cassini was one of the most complex space missions ever navigated. This required precise tracking of the spacecraft, and so for around six hours every day the Deep Space Network of radio dishes exchanged signals with Cassini. Distinct features of these signals allowed the Cassini team to track not only how far away the probe was (from the signal delay time), but also how fast it was travelling towards or away from Earth at the time (from the Doppler effect), and so reconstruct the spacecraft's trajectory.

Pinpoint accuracy

Now, Di Ruscio and his team have reanalysed this heritage Cassini navigation data and referenced the measurements to Earth's orbit in order to pinpoint the position of Saturn to metre-level accuracy. This is a staggering degree of precision and has enabled them to create one of the most accurate planetary ephemeris tables ever produced. So good, in fact, that they have been able to compare the actual orbital path of Saturn with predictions to determine how much Saturn's orbit has been perturbed by gravitational interactions from the Kuiper Belt. Taking into account the nine particularly large TNOs that are known about, and a series of three rings within the Kuiper Belt, Di Ruscio estimates that the total mass of the Kuiper Belt is around 3.6×10^{23} kg – or about 6 per cent that of Earth.

"An understanding of the masses of these TNOs would help to pin down any gravitational interactions from Planet Nine"

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

With this knowledge now in hand, astronomers will be able to calculate a much better picture of how this Kuiper Belt is being disturbed by a ninth planet, and where to look for it – if it does exist!

Lewis Dartnell was reading... *Analysis of Cassini radio tracking data for the construction of INPOP19a – A new estimate of the Kuiper Belt mass* by A Di Ruscio. **Read it online at: https://hal.archives-ouvertes.fr/hal-02881391**

The Milky Way's young runaways

A dozen youthful stars are circling the Milky Way much farther out than we think they should be

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Two and a half years ago, the Gaia collaboration released the second tranche of data from their mission to map the nearest billion stars. Ever since, astronomers have been picking through the treasure trove of data it delivered, publishing several papers a day using Gaia's measurements, and the flood of discoveries shows no sign of abating.

This month's paper adds some fast moving and unusual stars to the haul. Roberto Raddi in Barcelona and colleagues in Germany have sifted through the Gaia data to find 12 stars speeding through a region where they don't belong, far from the Milky Way's disc.

Though we generally picture the Milky Way as a thin disc with a central bulge – think of Patrick Moore's description of the Galaxy as 'two fried eggs, clapped back to back' – there are stars that exist above and below the disc, travelling on their own unusual orbits around the Galactic centre. Mostly, these stars have ended up there after long and eventful lives, but the unusual thing about the stars studied by Raddi and his colleagues is that they are young – young enough that we'd like an explanation for why they're so far from the densely populated disc where they must presumably have been born.

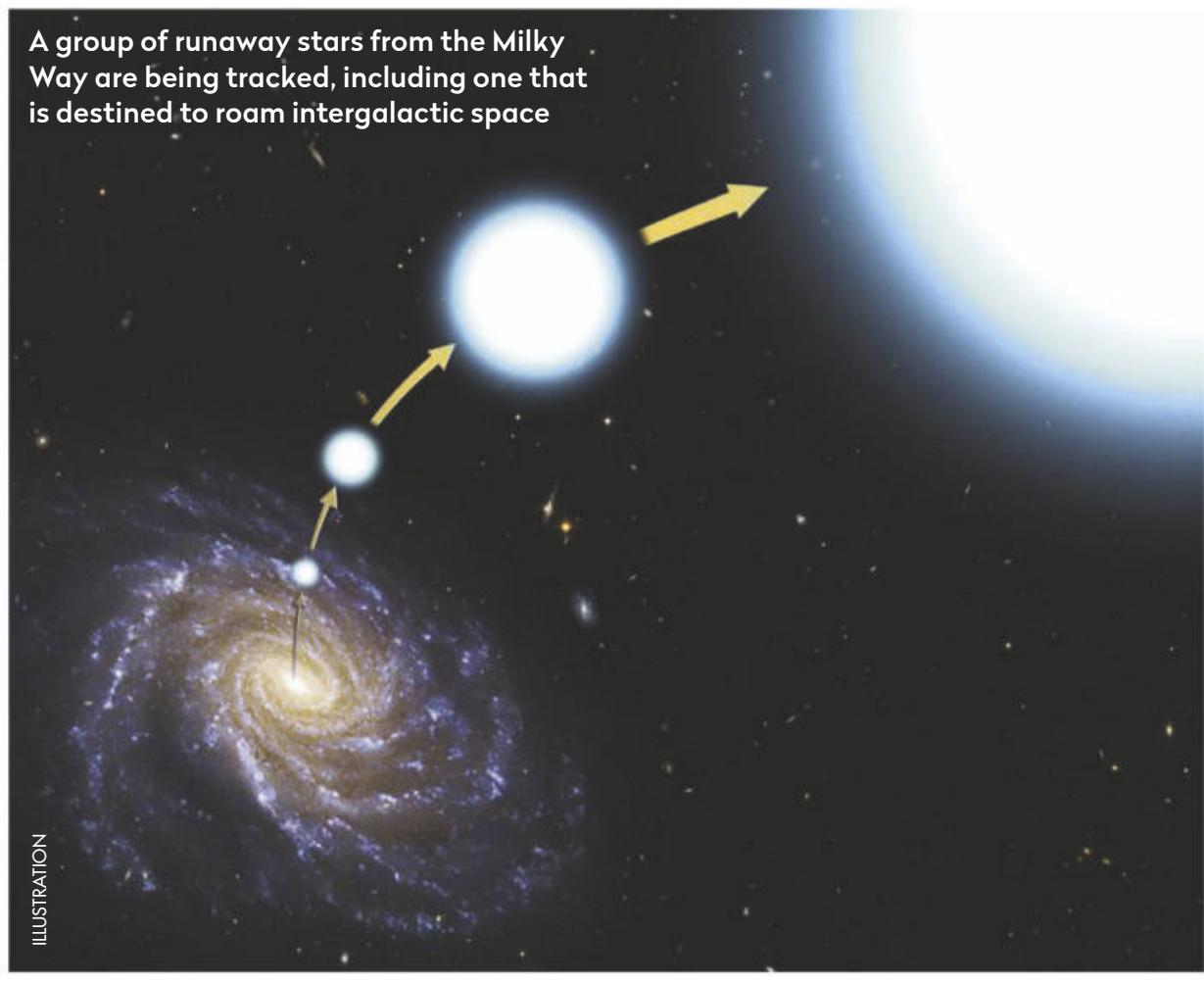
The outsiders

The stars in question were first identified in the Gaia database, and then their properties determined during a run on the New Technology Telescope in Chile. The runaway stars are between two and four solar masses, and the assumption is that most formed in the dense environment of a young open cluster. In such a cluster, occasional random interactions between the jostling stars may lead to the expulsion of one of the cluster's members. Alternatively, if one of the stars in a binary system goes supernova the surviving star may receive an almighty kick, being thrown out of the cluster and out of the disc of the Galaxy. Given their speeds and positions, this sort of origin story makes sense for nine of the stars.

"The unusual thing about the runaway stars is that they are young, so why are they so far from the disc where they were born?"

Three of the stars, though, are moving too fast for either of those mechanisms to be responsible. Our understanding of the physics involved in these mechanisms means that it turns out the maximum speed that can be reached is 450km/s, but three must have exceeded that. These stars, rushing away from the disc, present a true mystery – it's not at all clear how they came to be, and further work on more speculative possibilities for their origin is needed. Perhaps, somehow, they formed in the thin gas that surrounds the main disc.

However they set off on their current trajectories, the fate of these unusual stars is clear; 11 of the intrepid 12 will remain part of the Milky Way family, existing on orbits that take them high above and then far below our Galactic disc. One of the cohort, though, has a grander fate – 2207-4329 will join a select band of intergalactic wanders, spending the rest of its life out in the cosmic gloom.



A group of runaway stars from the Milky Way are being tracked, including one that is destined to roam intergalactic space

ILLUSTRATION

Chris Lintott was reading... *Runaway blue main-sequence stars at high Galactic latitudes. Target selection with Gaia and spectroscopic identification* by Roberto Raddi et al. **Read it online at: https://arxiv.org/abs/2011.08862**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

ILLUSTRATION DOTTEDHIPPO/ISTOCK/GETTY IMAGES, NASA/ESA AND G. BACON (STSCI), BBC

BBC News science correspondent **Pallab Ghosh** will appear on *The Sky at Night*'s January episode to discuss his space highlight of 2020

▲ Life on Venus? the detection of a possible life sign on our neighbouring planet Venus was the biggest science story of the year for the author

As a science correspondent for BBC News I get to cover lots of cool stories, but this year there's been only one story in town as far as the newsroom has been concerned. Don't get me wrong, the COVID-19 pandemic is arguably the biggest news story of our generation and as a journalist I'm glad to have had the opportunity to contribute to the BBC's coverage, but it's not as fun or uplifting as the topics that are my normal fare.

Then, in early September, I received a call from Steve Crabtree, *The Sky at Night*'s executive producer. He told me that the programme had "an incredible story" that would be of interest to our news platforms. I remember joking to Steve that unless it was the discovery of alien life it wouldn't get on because of the airtime COVID-19 was taking. There was a short pause on the line before Steve told me that he couldn't tell me what it was just now – only that it was a big story.

When Steve was eventually able to pass on the details, it was one of those jaw-dropping moments; I had to ask him to repeat what he had said, just in case I had got hold of the wrong end of the stick.

Signs of alien life?

Clearly it wasn't the definitive discovery of alien life – but it was the next best thing. And it was an enigma which only added to the story's charm. Researchers had a biosignature from our neighbouring planet Venus, one so hellishly hot and acidic that it's named 'Earth's evil twin'. It was thought to be one of the last places that life could exist – then comes the phrase that science journalists love to use – "until now"! The researchers had discovered a gas called phosphene in the Venusian atmosphere, something that can be produced by living organisms on Earth.

What's more, the gas was found to be short lived – so if there really are super-indestructible organisms in the planet's clouds, the critters are still there pumping the stuff out.

The research team had double-checked their findings using another telescope. They had carried

Pallab Ghosh is a BBC News science correspondent and a guest on *The Sky at Night* in January

out simulations and could not find an alternative explanation. Everyone's sensible side assumes that there has to be another process going on to produce the phosphene, but why be sensible when there was scope in this discovery for a scientifically sanctioned flight of fancy, especially in the context of the miserable year we've had with the pandemic.

Senior editors in my department are lovely people, but they can sometimes be quite serious and austere when talking about the news. After I told them about the Venus story, many of them became quite giddy with excitement when discussing it in their editorial meetings.

The Sky At Night's programme about the Venus discovery ('Life Beyond Venus', aired in November) got the science across beautifully. The natural enthusiasm of the scientist co-presenters Chris Lintott and Maggie Aderin-Pocock shone through, and the balance of the possibility of life and scepticism was just right. I loved the way Maggie's short pieces punctuated Chris's relaxed walkabout of discovery; between them they told a wonderful story – wonderfully!

For a moment they enabled us to put aside our worldly concerns and turn our thoughts to higher things, to make us feel the sense of awe and wonder that *The Sky At Night* so often brings.

Looking back: The Sky at Night

15 January 1989

On 15 January 1989, *The Sky at Night* investigated a 2,000-year-old mystery surrounding Sirius, the brightest star in the sky. If you look at the star tonight, you'd see it appears to be a bright white, but there are several sources from around the 1st century AD that refer to it as 'red', most notably Ptolemy in his star catalogue *Almagest*.

▲ An artist's impression of Sirius and its companion star, Sirius B (right)

Modern astronomers first began debating what could have caused the shift in 1760, when Thomas Barker presented the matter to the Royal Society. One suggestion was that the white dwarf that orbits Sirius, known as Sirius B, was at the tail end of its red giant phase. However, it would take much longer than 2,000 years for it to fade from being bright enough to make Sirius look red to what we see today.

What seems most likely is that the Ptolemy and his cohorts were mistaken, especially as other contemporary astronomers from Rome and China refer to the star as 'sea-blue' or 'white'. As Sirius was often associated with heat and fire, it could also be that Ptolemy was referring to the star as red in a more metaphorical sense.

Pick of the Year

Maggie and Chris look back on 2020 with a selection of highlights from the past year of *The Sky at Night*. Some famous faces from the world of space and astronomy will pick their own favourite memories from 2020, and the team will also be selecting the top highlights suggested by viewers and readers of *BBC Sky at Night Magazine*. Will your personal pick make the list?

BBC Four, **10 January**, 10pm (first repeat BBC Four, **14 January,** 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ Will September's announcement about the discovery of phosphine in the clouds of Venus make it into this year's highlights?

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize:
four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, Heather Couper and Nigel Henbest's *2021 Stargazing*, and a planisphere for the night skies as they appear at latitude 51.5° north.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Catching the Moon's libration

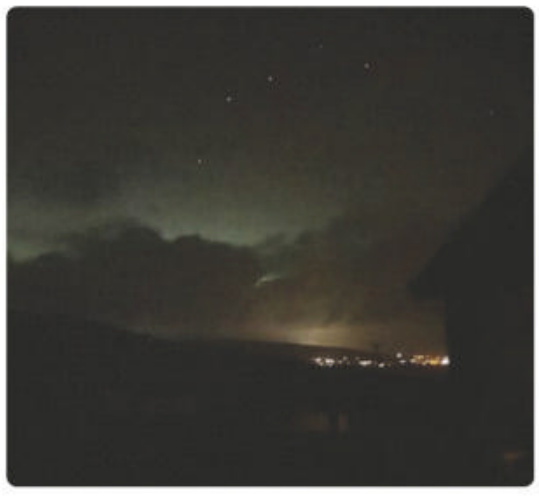
I've been a hobby astronomer for quite a few years and I've always enjoyed taking pictures of the Moon, usually collecting full Moon images each month to make a collage at the end of the year. I was inspired by Pete Lawrence in October 2020's issue ('Imaging lunar libration', page 76) to capture and compare October's two full moons and look at the differences in positions caused by lunar libration (the Moon's small rocking and rolling motion). What began as the comparison photo here developed into an overlay photo, then with help from my daughter I also made a video to show the movement!
Kate Hillis, South Yorkshire

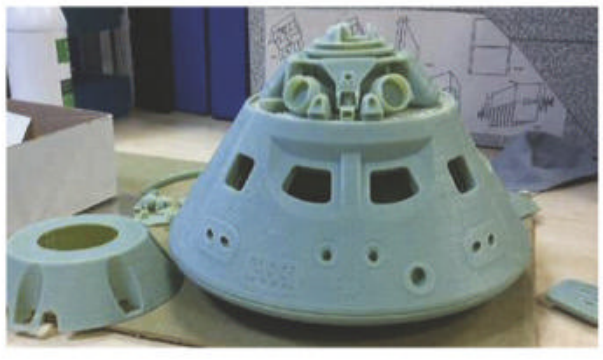
Delighted that the article has proved so engrossing, Kate! It shows the Moon's 'wobble' is surprisingly noticeable when you track it. ***– Ed.***

Kate's full Moon images capture extra areas of its surface

Tweet

Karen Hall
@kazcustard • Nov 22
Things to do in a howling gale part 2: hide in front of the garage to try & get a non shaken picture of tonight's #AuroraBorealis #Mirriedancers #northernlights #Shetland





▲ Mark's 3D-printed model of the Orion Crew Module won praise from NASA

Model Module

I teach computer-aided design (CAD) in the Midlands and was recently putting together a poster for coursework, which had me looking for a 3D model of NASA's SLS rocket. I couldn't find one I could work with, so I started putting a CAD model together and for several weeks got fixated on creating designs for a 3D-printed model of the Orion Crew Module. I shared my efforts on NASA's Orion Facebook page and the response was humblingly positive, with 'Likes' from many staff at NASA, including the ex-program manager for Orion and the program planner on the Orion spacecraft! In case any readers have 3D printers, the Orion 3D-model designs are on a website called GrabCAD (**https://bit.ly/3o83i3D**), where there's a free download. I was lucky to grow up at a time when Airfix, Revell and Monogram models were inspiring kids, and I hope this 3D model will do a bit of the same!
Mark Piatowski, Solihull College and University Centre

Fond farewell

The Arecibo Observatory in Puerto Rico is a byword to a generation for exciting science. Hopefully someone in the know will write 'the book' on this historical triumph. Sadness is already circulating the globe after news of its closure.

David S Truman, Stockport

If the cap fits

I just wanted to say thank you very much for the article by Martin Lewis ('How to collimate a Newtonian telescope', page 74, October 2020 issue). It explained collimation in a most clear and straightforward way. It has enabled me, for the first time, to successfully and confidently collimate the mirrors in my own telescope. I have owned a Cheshire eyepiece for some time, but in the past I couldn't quite work out what to do with it. Martin's article made the process very easy. There is just one thing that I did differently; for the second stage of the collimation – aligning the primary mirror – the crossed wires in the eyepiece got in the way of the crucial part of the view. I resorted to a collimation cap – which had also been sitting in my drawer for a while. Using this, the view was perfectly clear and the procedure very straightforward. I just thought I would mention that in case it is in any way useful! Thanks again for a great article and for a great magazine.

Tim Ellison, via email

Shower power

I see in the 'Sky Guide' that you mentioned the Iota Aurigid meteor shower on 15 November (November 2020 issue, page 45). It's not one I'd heard of and looking into it I discovered that it is no longer recognised by the International Meteor Organisation (IAU), having erroneously thought it to be a meteor shower. It's now considered to be a mix of the November Theta Aurigids (peak around 26 Nov, rate <1) and the Chi Taurids (peak around 4 Nov, rate <1). I don't think a combined rate of 8.2 is likely! While it's good to get people out looking for meteors you don't want to over-egg the pudding, as ▸

ON FACEBOOK

WE ASKED: What are your New Year's resolutions?

Anj Dhunna To try and get away and see if I can catch a glimpse of the Milky Way; at least it'll be one thing off my bucket list!

Brian Smale I will have retired and stopped working around the world, so I intend to stay home and use my telescope more often and attempt astrophotography.

Mick Cassidy Try and upgrade to a nice mount and OTA to go along with my Dobsonian and maybe try astrophotography.

Gareth Parsons To do more stargazing and astrophotography. Also to make the most of breaks in the clouds.

Gemma 'Boudica' Smith To get out to low light emission areas with my 10-year-old son and show him how beautiful the night sky can be.

Michael Bate Get my hands on some SHO filters.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I'm just getting started in astronomy, but arthritis makes it a struggle to look through my Celestron Powerseeker 76AZ. Can you suggest a setup that will help me observe more comfortably?

KEVIN JUDD

▲ The Celestron Astro Fi 125mm works well with a smartphone

The viewing angle is often a problem and your Celestron Powerseeker 76AZ Newtonian reflector will present a wide range of viewing heights – low when viewing objects close to the horizon and high when observing closer to the zenith. There is a telescope design called a Nasmyth telescope that maintains a constant viewing position, but these are rare and eye-wateringly expensive!

To minimise the range of movement, you might consider buying a short-tube scope like a Schmidt-Cassegrain (SCT) or Maksutov Cassegrain (MC). The star diagonal that takes their eyepieces could be orientated so that it points sideways to make observing more comfortable. These instruments fold the light path into a short length tube but have long focal lengths starting at 1,250mm for a 5-inch SCT or 1,500mm for a 5-inch MC, making them mainly suitable for Solar System objects, star clusters and galaxies.

If you have a smartphone, the Celestron Astro Fi 125mm Schmidt-Cassegrain (SCT) would suit or, if you prefer a wired hand controller, the Sky-Watcher Skymax 127 SynScan AZ Go-To Maksutov Cassegrain would be a suitable upgrade.

Steve's top tip

What is a guidescope?

Although modern equatorial mounts designed for astro imaging can track accurately, most require assistance to keep them perfectly aligned with the object being imaged, in order to maintain round stars. This can be accomplished by installing a second, smaller telescope called a 'guidescope' fitted with a simple camera onto the main imaging scope. This guidescope/camera, in combination with autoguiding software, captures images of a single star and notes any change in its position on the camera's sensor; if the tracking has slipped, a command is sent to the mount to correct the error.

Steve Richards is a keen astro imager and an astronomy equipment expert

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Instagram

photoknoxy • 23 November

From last night, four shots showing an A320 crossing the face of the moon (it's aircraft EI-DEO). Processing has managed to bring out some of the lunar surface colour - apparently due to different concentrations of titanium and aluminium compounds... @aerlingus @airbus @bbcskyatnightmag @bbcnorthwest @owainwynevans #moonphotography #lunar #lunarphotography #night #nightsky #astro #canon #cheshire #bbcnorthwest

▸ people will come away disappointed!
Brendan Shaw, via email

We don't normally include really low-rate showers but with the Moon being favourable for the Iota Aurigids, it was a good opportunity. The Iota Aurigids' declassification as a new shower demonstrates the dynamic nature of meteor astronomy and doesn't mean observing around this period is any less important: even though showers get re-labelled and distributed among other sources, the meteors will still be there and may be observed. ***– Ed.***

Too many equations

Following Giles Sparrow's review of Professor PJE Peebles's book *Cosmology's Century*, (June 2020 issue, page 86) I bought a copy. I have to ask, did Mr Sparrow review the same book? He wrote, "The use of equations is sometimes unavoidable... but the gist of his arguments and stories remains easy to follow...". This didn't ring true: the many equations are the substance of the book. I showed it to my granddaughters who are doing second year A-level maths and they said it was far beyond them! A mention that this is an undergraduate or post-graduate level book would have been helpful for an average reader.
Derek Marsh, via email

SOCIETY IN FOCUS

The **Astronomy Section of La Société Guernesiase** was founded in 1972. We are an active group of about 60 members, welcoming anyone with an interest in astronomy. We meet at our Observatory, whose main building was constructed in 1943 during the German Occupation as part of the Mirus gun battery complex. Today it houses a meeting room, and an adjoining library and kitchen facility, opened in 1991 by Heather Couper and Nigel Henbest. Our roll-off roof observatory was opened by Sir Patrick Moore in 1993.

We meet on Tuesday evenings and have informal presentations on various astronomical subjects. Weather permitting we open the observatory, which houses an equatorially mounted 16-inch Meade SCT reflector and a 5-inch Takahashi refractor. We have a selection of refractors on equatorial mounts as well as other scopes, including a Sky-Watcher Esprit 80mm on an HEQ5 mount, a Celestron SE8 and a 12-inch Dobsonian. We also have a Starlight Express all-sky camera that gives live sky views on our website.

▲ David Le Conte, a founder member of the society who sadly passed away this year

We run courses during the year and lectures on cosmology and other topics. We also offer educational outreach and encourage new members to visit the club to try our scopes. The island has very few COVID-19 cases; since lockdown ended on 1 June, we've been able to meet weekly.
Allan Phillips, equipment officer, La Société Guernesiase Astronomy Section
▸ www.astronomy.org.gg

COVID-19

Online and socially distanced events taking place this month

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

CITIZEN SCIENCE

Track a TNO

Get involved in this project to discover hidden Trans-Neptunian Objects (TNOs), icy and exotic outer Solar System worlds. Volunteer eyes are needed to study animated images from the Catalina Sky Survey and determine which objects are real TNOs. **bit.ly/2Uxvkck**

ONLINE TALKS

Glasgow lectures

The Astronomical Society of Glasgow has a series of Zoom and YouTube lectures planned for the coming months, starting with 'Black Holes: 100 Years of Mysteries' on 21 January with Dr Fabio Biancalana and 'Apollo 50' with Robert Law on 18 February. See the Society's website for login details: **www.theasg.org.uk**

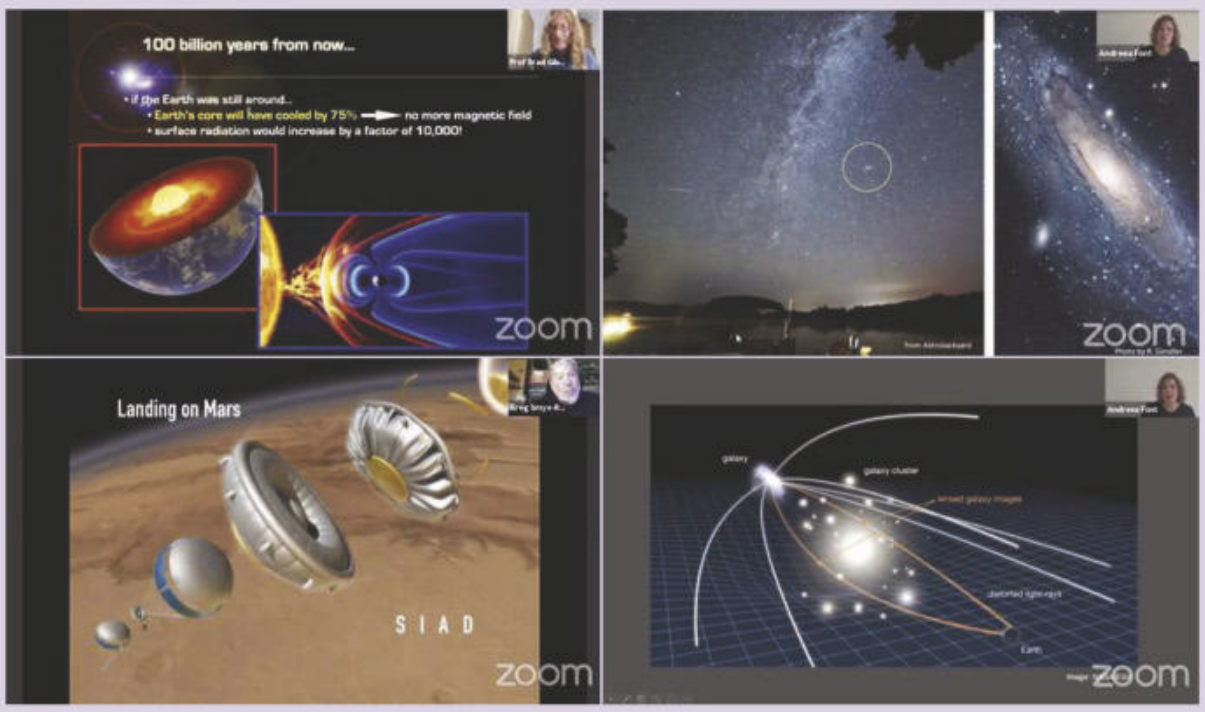
Sunderland astro chat

Using Zoom, Sunderland Astronomical Society (SAS) is offering advice and chat on telescopes, cameras, observing techniques and anything else astro-related. Their meetings this month are on 3 and 10 January at 7pm and open to all. To join one, just send an email request to **zoom-meetings@sunderlandastro.com**

Northern Scotland talks

Catch up with the latest in northern Scottish astronomy with videos that were part of Orkney International Science Festival 2020: 'Finding Planets Around Other Stars' from Moray's Astronomy Club, a discussion of plans for a spaceport in Scotland, and 'The Orkney Night Sky for Beginners', courtesy of the Highlands Astronomical Society (who also recently branched out into live observing webcasts). **bit.ly/32QrQ9g**

PICK OF THE MONTH



▲ Expert views: you can live stream a wide range of webinars at the BAA's YouTube channel

British Astronomical Association

Deepen your astronomy knowledge in 2021

If you've already got a handle on equipment basics and brushed up your observation skills, why not resolve to make 2021 the year you dig deeper into the science of astronomy?

On hand to help is the BAA (British Astronomical Association). The amateur astronomy organisation's website features numerous expert articles and tutorials, plus online talks. Recent webinars include Adam Block's 'The Interpretation of Astronomical Images' and Brad Gibson's 'How the Universe Will End'. To watch them head to BAA's YouTube channel.

Digital membership starts at £30.50 and benefits include the *BAA Journal*, a member chat forum, and the expert-run Observing Sections, providing guidance on a plethora of topics from aurora to exoplanets. **www.britastro.org**

ONLINE COURSES

Introduction to Astrophysics 2020/21

Investigate the physics of our Universe in this six-week course from the Royal Observatory Greenwich, covering Solar System exploration, exoplanets, dark matter, cosmology and the Big Bang. Ideal for people with some prior knowledge of astronomy. Tuesdays, 7–9pm, 5 January to 9 February, via Zoom webinar. Cost: £96. Book a place here: **bit.ly/36HwSWM**

LIVE EVENT

Private stargazing experience

With a large telescope provided and the starry vista of some of the UK's best dark-sky spots, enjoy a one- or two-hour private guided stargazing experience. Individuals, couples and families from the same household/social bubble can expect enthusiastic narration and a laser-guided tour of the views by an expert astronomer. From £125. **stargazingexperiences.co.uk**

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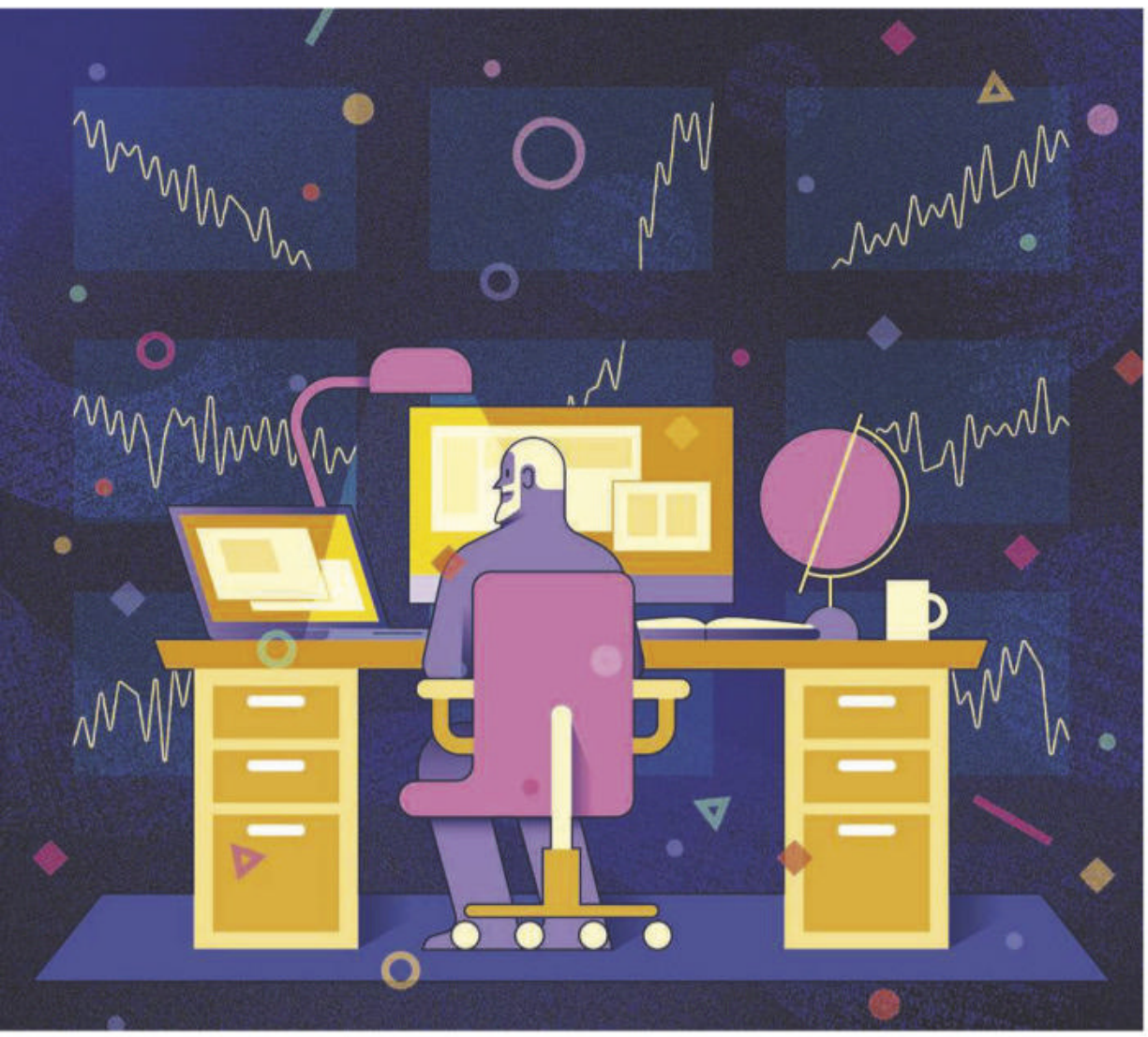
FIELD OF VIEW

Classifying stars by consensus

Lewis Haley recounts the thrill of being part of a Zooniverse citizen science astronomy project that draws on input from a global network of participants



Lewis Haley is a student of the Universe with a thirst for variable stars. SuperWASP and Zooniverse provide, where his own telescope does not. Find Zooniverse live space projects at **bit.ly/2UYkZWO**

SuperWASP is an experiment in a long line of research projects with names so fantastical one might be forgiven for believing the choice of acronym precedes the name. The Wide Angle Search for Planets (WASP) scoured the whole sky (excluding the galactic plane) every night for 10 years, to find exoplanets orbiting distant stars. It turns out, taking photos of the whole sky every night captures the whole sky, every night – surprising, I know.

I was introduced to the mass of SuperWASP data while studying astrophysics with the Open University. Using this data as a guide, my team and I observed variable stars using the PIRATE telescope (another great name) on Tenerife, hunting for as much information as we could. I was hooked and I wanted more; I wanted to spend every waking moment staring at graphs that so succinctly describe how stars behave. My poor wife was only too happy to hear all about that new EW-type of contact binary with an unusually high amplitude that I had just identified... I must remember to buy her flowers.

I was delighted when the SuperWASP Variable Stars Zooniverse project went public in 2018, presenting 1.6 million objects as light curves plotted on a graph of flux against phase for the public to interpret; my wife was "thrilled". Each point on the graphs represents the brightness of the star in a single image taken at a specific time and date. The data benefits from a high cadence and a long baseline, meaning many observations per night for many, many nights, creating dense graphs from which stellar characteristics can be identified with relative ease.

The aim of the game, on the Zooniverse project's website, is to match the given graph to one of six categories of light profiles. There's a handy field-guide detailing the categories, with further details on subcategories. Some are easy to identify, some not so much; but there's no need to panic, decisions made here are not final. The final classification is based on a consensus, with professional oversight, and you won't get in trouble if you get it wrong.

Once a star has been classified, there's an opportunity to discuss it. You can ask questions, make comments, or provide any more detailed information you might glean from the graph. It's at this point you realise you are part of a wider public community – a collective of people all working towards the same goal – to understand the Universe. That's why I do it. To be part of the scientific community, hell-bent on knowing more about everything. The discussion section is where you'll find handy hints and links to additional resources, as well as other people with a rich knowledge on the subject.

This Zooniverse project is something you can get involved with as and when you fancy. There are no annoying deadlines; I do it in those rare spare moments. I'd be lying if I said my wife hadn't knocked on the bathroom door more than once to check I'm Okay. Of the 1.6 million light curves, together we have classified around 750,000... Send help!

KIK LJUNG/FOLIO

BBC

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SPACE IN 2021

Next year will see more people heading into space than ever before and three different missions arriving at Mars. **Ben Evans** looks into why 2021 is shaping up to be a great year in space

MARS: APHELLEON/ISTOCK/GETTY IMAGES

Sixty years ago, with Russia and the United States at each other's throats, space exploration was a pawn in a wider campaign for geopolitical and ideological supremacy. When Yuri Gagarin travelled into Earth orbit in April 1961, the rockets of his day were little more than converted weapons of war.

Today, problems between nations remain fraught, but against many odds space exploration has thrived. Countries which once aimed rockets at each other now use the descendants of those rockets for peaceable ends. Former enemies work side by side on the International Space Station, sending missions to Mars seems almost commonplace and our tiny position in the cosmos has been revealed as never before. Having endured one of our worst years in recent memory, space exploration stands apart as a sphere where 2021 has a truly optimistic outlook. ▸

Destination Mars: with three missions heading for the Red Planet in 2021, it feels like it has never been closer to our planet

ILLUSTRATION

Super power: NASA's Space Launch System (SLS) will spearhead a new era of lunar exploration

ILLUSTRATION

HUMAN SPACEFLIGHT

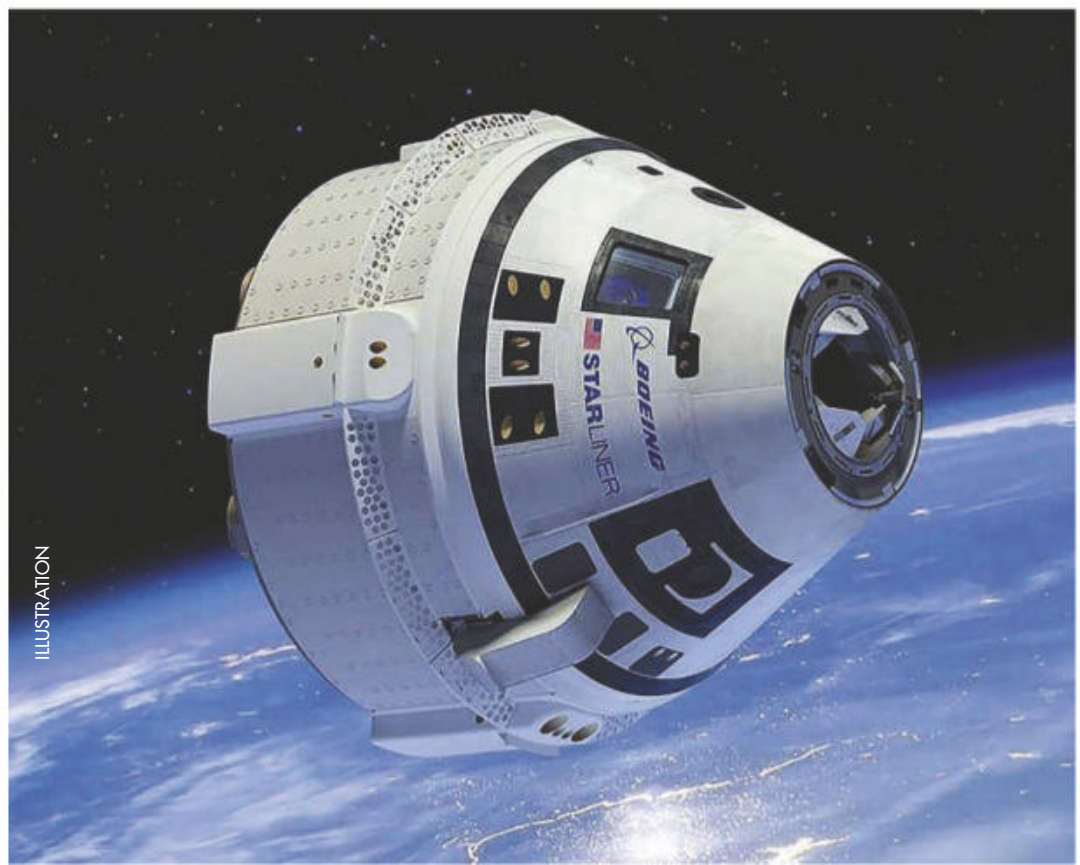
While NASA sets its eyes on returning people to the Moon, commercial spaceflight is looking set to take over low-Earth orbit

A rocket larger and more powerful than any in the world will open a new chapter in human spaceflight in 2021, as Florida reverberates under 39 million Newtons of thrust. NASA's mighty Space Launch System (SLS), fitted with four refurbished Space Shuttle engines and a pair of five-segment solid-fuelled boosters, will roar aloft from Pad 39B of the Kennedy Space Center (KSC) for Artemis-1, the inaugural flight of an Orion crew capsule to the Moon. It will mark the first time that a ship built to carry people has crossed the 384,400km gulf to our closest celestial neighbour in almost half a century. And if all goes well, another hurdle will be cleared as NASA aims to plant human boots on lunar soil by 2024.

With Orion already in Florida and deep into processing for its two million-kilometre journey, the launch date hinges on the progress of the SLS itself. Its boosters arrived at KSC in June 2020, to be joined by the 21-storey core stage after it completes a lengthy bout of testing. These gargantuan rocket parts will be fitted to an interim cryogenic propulsion stage to push Orion out of Earth orbit and onward to the Moon. It promises to be nothing short of a game-changer in our exploration of deep space.

Although the eyes of the world will undoubtedly be focused on the uncrewed Artemis-1 mission, people will continue to fly into space in 2021. The Commercial Crew Program will finally hit its stride with Boeing's Starliner and SpaceX's Crew Dragon ships. Starliner is set for an uncrewed mission in January, before three NASA astronauts climb aboard

▼ Going the distance: Boeing's Starliner will take astronauts to the International Space Station (ISS)



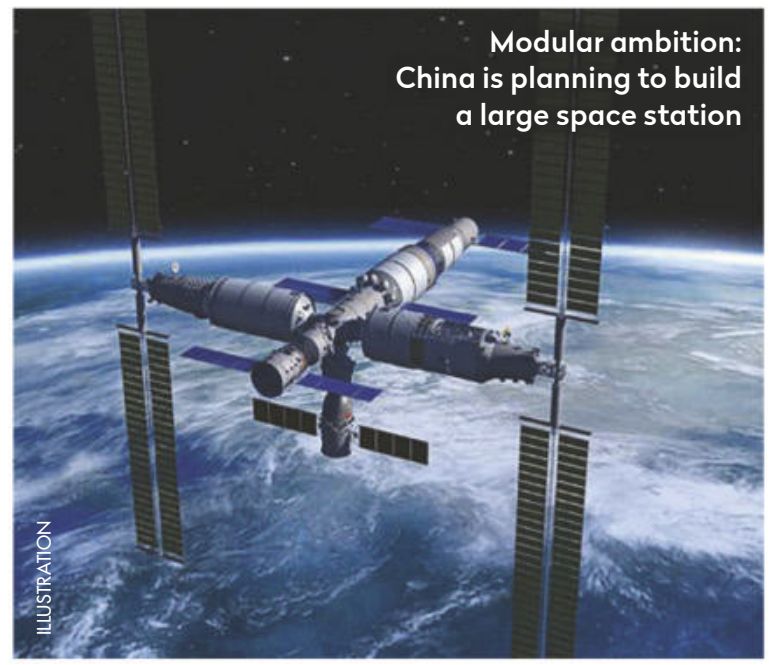
ILLUSTRATION

NASA/MSFC, BOEING, NASA TV, UPI/ALAMY STOCK PHOTO, ZUMA PRESS INC./ALAMY STOCK PHOTO, CMSE

▲ Success stories: SpaceX has already flown two crews to the ISS; the latest, Crew-1 (above in red shirts), docked on 16 November 2020...

► ...and a recent test launch in Texas of the SpaceX Starship rocket went to plan

Flying VirginGalactic: the company anticipates its first spaceflights in 2021



Modular ambition: China is planning to build a large space station

ILLUSTRATION

for an all-up test flight to the International Space Station (ISS). Meanwhile, Crew Dragon will rotate ISS crews in the spring and summer, helping to maintain a permanent presence of seven humans aboard the sprawling orbital outpost.

Space tourism... and movies

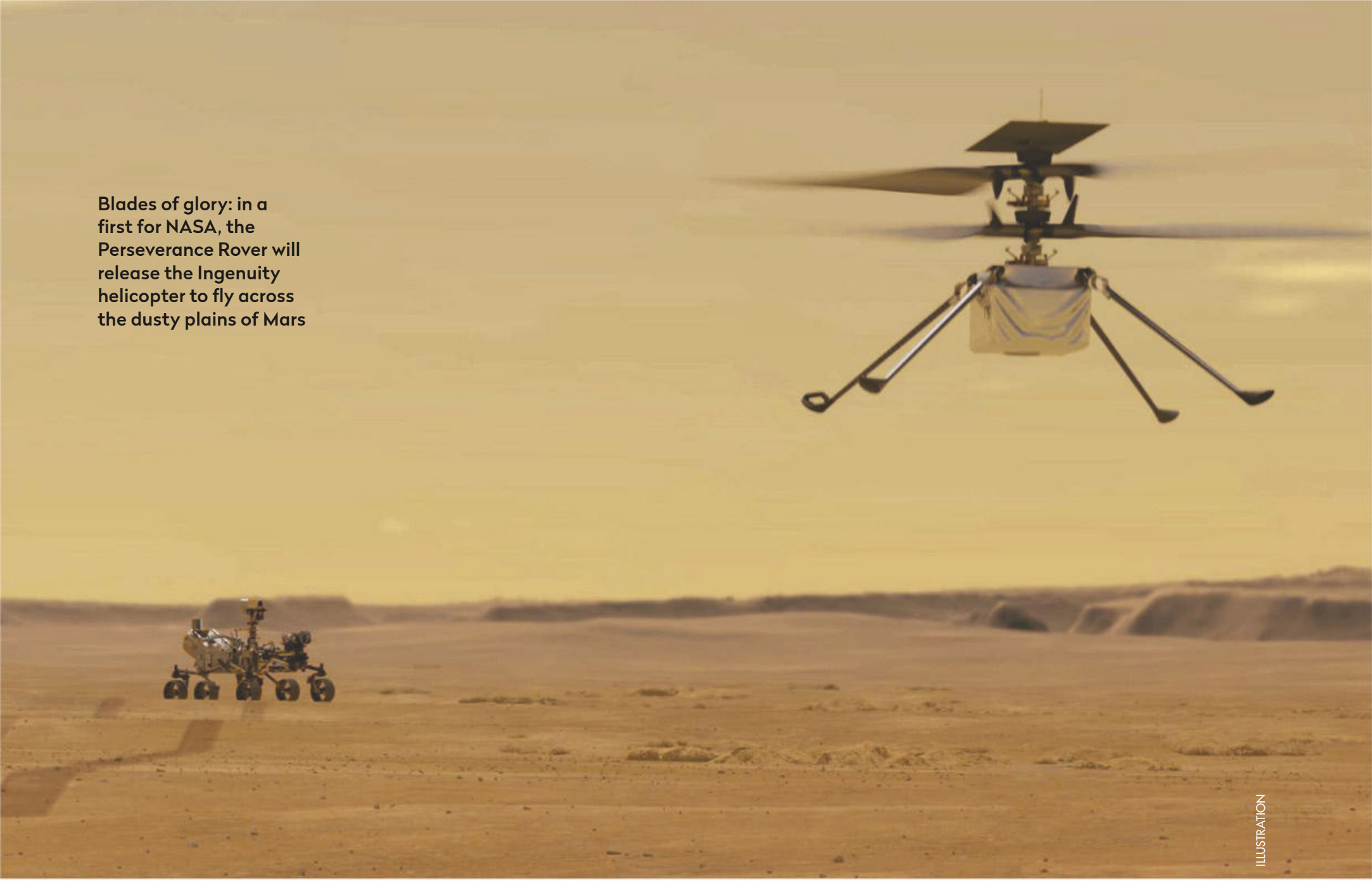
And with Crew Dragon also lined up for other clients, the Houston-based Axiom tourism firm is aiming for its maiden flight in 2021. Its crew features a former ISS commander, Hollywood film star Tom Cruise and producer Doug Liman to shoot part of a movie on the station. Three Russian Soyuz missions are also planned, one of which includes a pair of tourists.

The ISS itself will change physically next year, with the departure of the long-serving Pirs docking hub to make room for Russia's large Nauka science lab in April. A new 'node' called Prichal will then arrive in September. Add to that 10 cargo deliveries (including the first flight by Sierra Nevada's Dream Chaser spaceplane) and the station promises to be an exceptionally busy place.

SpaceX is also midway through an extensive test programme at its Boca Chica facility in Texas for Starship, a next-generation launch vehicle that NASA picked in April 2020 as a candidate for returning humans to the Moon. Standing 120m tall and weighing 5,000,000kg in its final form, small-scale Starship tests began in April 2019 and attained altitudes as high as 150m. Plans to climb incrementally higher are in progress and Starship may take its first commercial payloads into space in 2021.

Having already sent men and women into orbit under its own steam, China is planning a large modular space station, whose 'core' — the 19m-long Tianhe living quarters — might fly atop a Long March 5 booster in 2021. In its final configuration, it will be a fifth as big as the ISS, with a pair of 15m-long science labs and power-producing solar arrays. India, too, is prepping two uncrewed flights of its three-person Gaganyaan spacecraft. Work was stalled by the steady spread of the COVID-19 pandemic, but the South Asian country still hopes to send its first national astronauts into space as soon as December 2021.

And 60 years after Yuri Gagarin's pioneering voyage, Virgin Galactic anticipates its first passenger flights to the edge of space. Already, its SpaceShipTwo vehicles successfully exceeded 80km in altitude in December 2018 and February 2019, securing commercial astronauts' wings for their crews in the process. Two new test pilots were recently hired, expanding Virgin Galactic's flying corps for a robust series of fare-paying trips in 2021. In addition to two qualified pilots, each flight can carry up to six passengers. ►



Blades of glory: in a first for NASA, the Perseverance Rover will release the Ingenuity helicopter to fly across the dusty plains of Mars

ILLUSTRATION

PLANETARY EXPLORATION

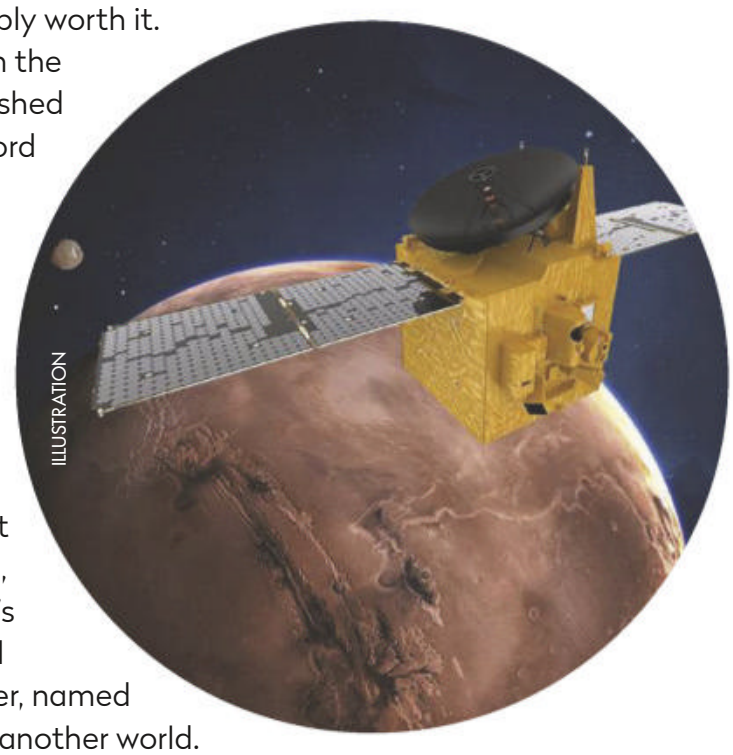
There's a lot going on in our Solar System this year – from one mission making it to Mercury, to another meeting its end at Jupiter

On 18 February 2021, seven minutes of sheer terror (for NASA mission controllers, at least) will herald the dawn of our next phase of Mars exploration. After seven months in flight and around 480 million kilometres travelled, NASA's one-tonne Perseverance rover – guarded by its sturdy heat shield – will finally reach the Red Planet. It will plunge into Mars's thin atmosphere at 20,000km/h, heading for a landing in the 45km-wide Jezero Crater, just north of the equator. Supersonic parachutes, a rocket-propelled 'sky crane' and a pinch or two of old-fashioned good fortune will guide it down to the surface of an alien world.

Its hazardous descent is nothing new. In August 2012, the Curiosity rover followed an almost identical route and not only survived landing, but is still fully functional, still roves the ochre-hued plains of Mars and still gathers data to this day. But Perseverance is encumbered with an entirely new set of challenges. It will alight on the surface within a much smaller 'landing ellipse' than Curiosity did and attempt to reach an area littered with craters, boulders and possibly an ancient river delta.

Sheer madness, you might think, but the prize at the end is demonstrably worth it. For Jezero might contain the remnants of a long-vanished lake. (In fact, the very word 'jezero', in Slovenian, means 'lake'.) And it might be a promising location to sample water-bearing clays and carbonates. Perseverance will attempt to sniff out the 'biosignatures' of ancient life, gather rock samples, measure the Red Planet's dust-driven weather and deploy the first helicopter, named Ingenuity, ever flown on another world.

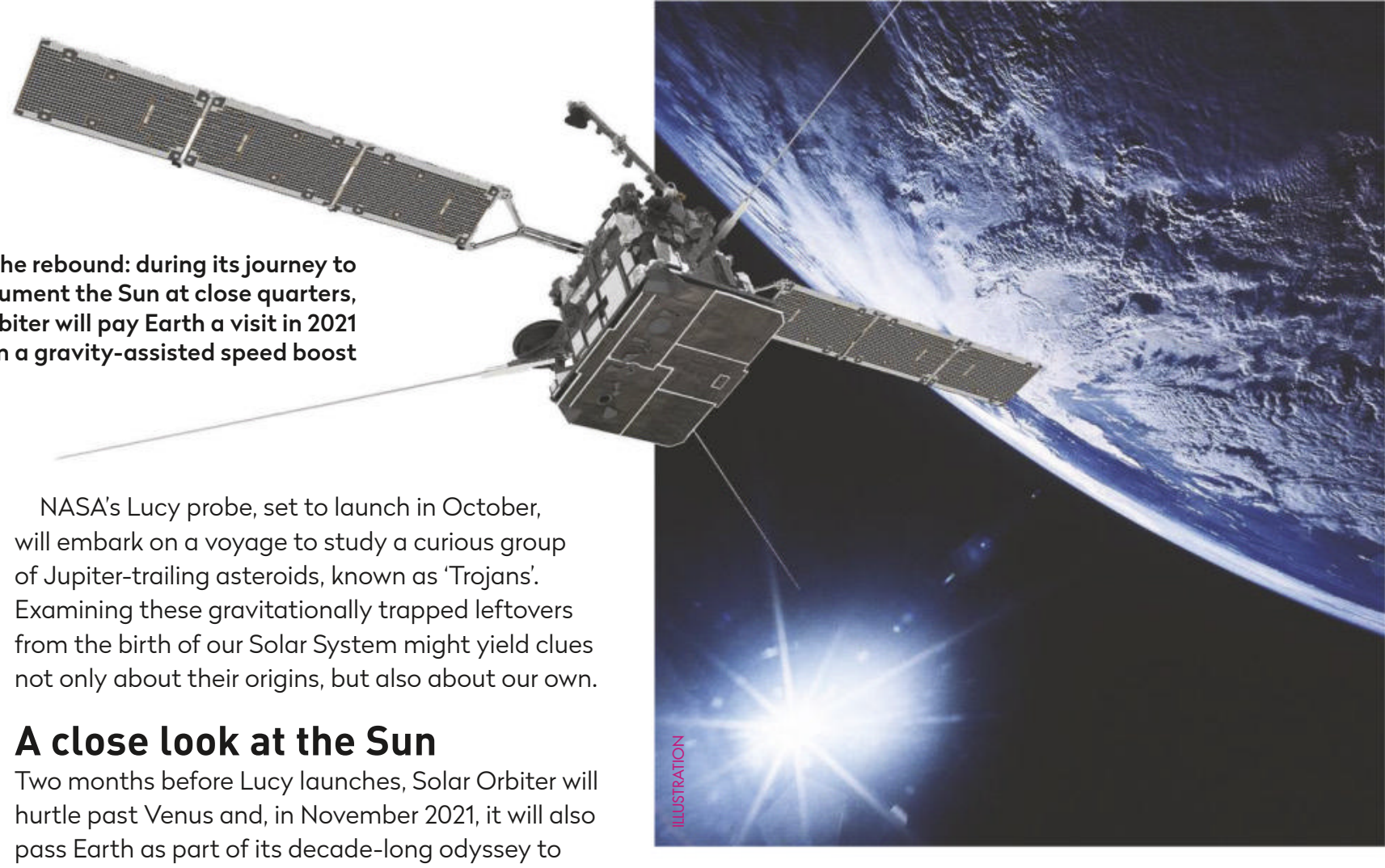
That endeavour alone offers more than enough to inspire future generations, but 2021 has other contributions to make. The United Arab Emirates (UAE) is sending its own Hope orbiter to Mars, as is China, whose Tianwen-1 mission also includes a rover equipped with ground-penetrating radar.



ILLUSTRATION

▲ Up in the clouds: UAE's Hope mission will explore the atmosphere of Mars

NASA/JPL-CALTECH, MBRSC (MOHAMMED BIN RASHID SPACE CENTRE), SPACECRAFT: ESA/ATG MEDIALAB/MERCURY: NASA/JPL, ESA/ATG MEDIALAB, IMAGE DATA: NASA/JPL-CALTECH/SWRI/MSSS, IMAGE PROCESSING BY KEVIN M. GILL/© CC BY



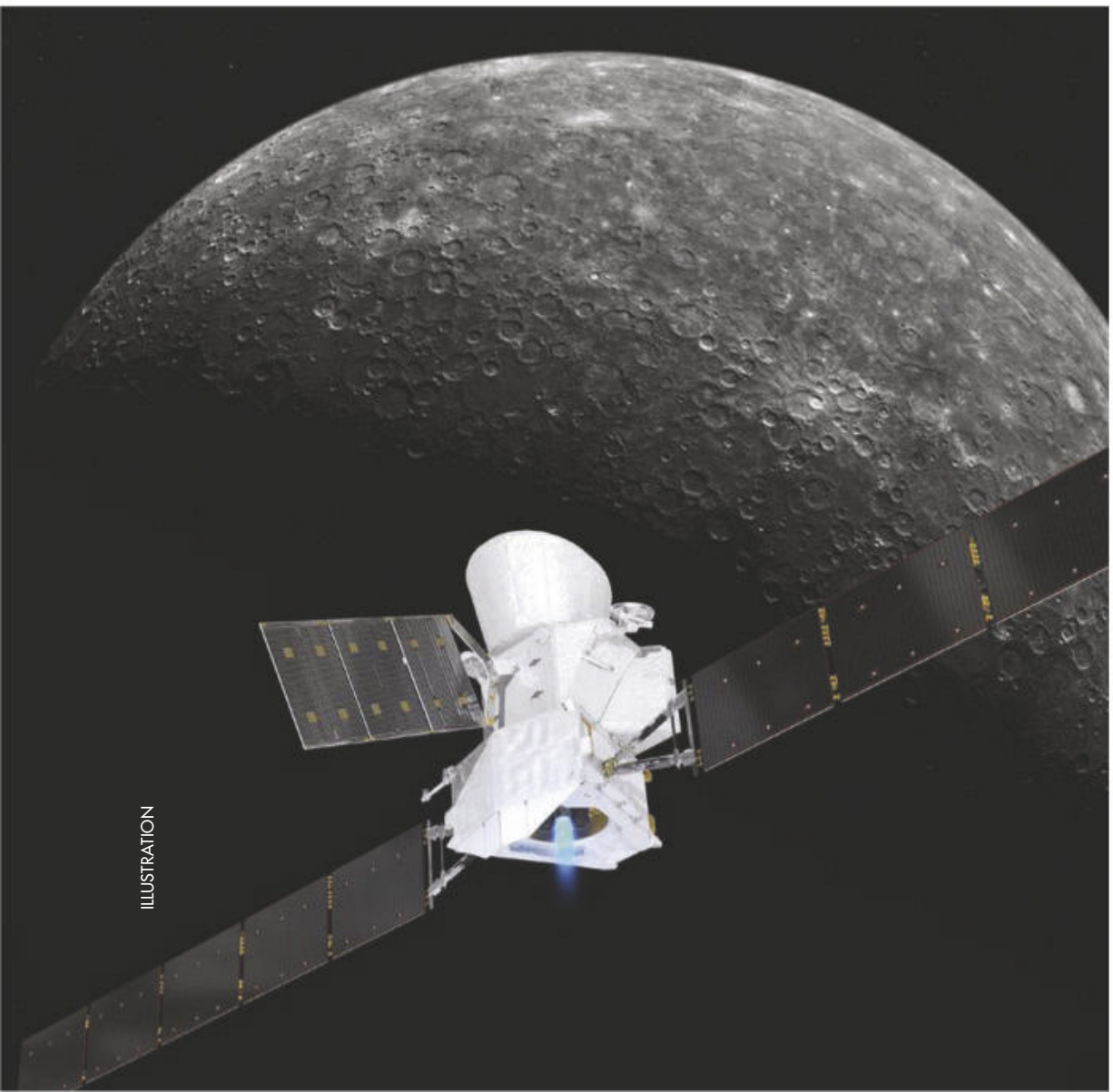
► **On the rebound: during its journey to document the Sun at close quarters, Solar Orbiter will pay Earth a visit in 2021 to gain a gravity-assisted speed boost**

NASA's Lucy probe, set to launch in October, will embark on a voyage to study a curious group of Jupiter-trailing asteroids, known as 'Trojans'. Examining these gravitationally trapped leftovers from the birth of our Solar System might yield clues not only about their origins, but also about our own.

A close look at the Sun

Two months before Lucy launches, Solar Orbiter will hurtle past Venus and, in November 2021, it will also pass Earth as part of its decade-long odyssey to get up close and personal with our parent star. The probe and its heavy-duty heat shield will perform several Venus 'gravity-assists' to creep to within 60 solar radii, a third of the distance between Earth and the Sun. It promises Solar Orbiter a splendid (though blisteringly hot and extremely risky) ringside perspective of our star's majestic fury. Working in tandem with the 2018-launched Parker Solar Probe, it will investigate energetic plasmas, the mysterious heating mechanism behind the glowing corona and the nature of the solar wind.

Indeed, Venus will be a busy stopping-off place for spacecraft in 2021. Not only will Solar Orbiter pay it a visit, but so too will the ESA/JAXA mission BepiColombo. While the Solar Orbiter will return to Venus time and again, BepiColombo will do so once; the fleeting encounter will reshape the spacecraft's orbit to reach its own destination under optimum



ILLUSTRATION

▼ **Inner world: BepiColombo is travelling to Mercury, the closest planet to the Sun**

ILLUSTRATION

▲ **Farewell to Juno: the plucky probe will burn up in Jupiter's atmosphere in the summer of 2021**

conditions. And that destination is not Venus or the Sun, but the Solar System's innermost planet, sparsely-explored Mercury. In October 2021, BepiColombo will perform the first of six flybys of Mercury, before entering orbit around this diminutive world. That same month, Russia's Luna 25 mission will also launch, bound for Boguslavsky Crater, near the Moon's south pole, with Astrobotic's Peregrine lunar lander also due to fly atop the first Vulcan Centaur rocket.

As these missions begin, others will inexorably approach their end. OSIRIS-REx, which in October 2020 triumphantly touched the surface of asteroid Bennu, some 321 million kilometres away, and captured soil specimens with its touch-and-go sampling head, will begin its 30-month trek back to Earth in March 2021. And the curtain will also descend on the long-serving Juno spacecraft, which has for five years unveiled the internal dynamics of Jupiter in unrivalled detail and returned astonishing views of its colourful clouds from polar orbit. Juno will breathe its last in July 2021, with a destructive dive into the atmosphere of the Solar System's largest planet. ►

Timeline

With dozens of missions set to reach a milestone, 2021 is going to be a busy year

EARLY JANUARY: Boeing Starliner uncrewed test flight

18 FEBRUARY: NASA's Perseverance rover lands on Mars

FEBRUARY: Emirates Mars Mission enters Mars orbit

11–24 FEBRUARY: CNSA's Tianwen-1 mission enters Mars orbit

MARCH: NASA's OSIRIS-REx departure window from Bennu opens

APRIL: Tianwen-1 lands on Mars

APRIL: SpaceX Crew Dragon mission to International Space Station (ISS)

APRIL–MAY: ISS module Pirs detaches from ISS; Nauka launches

APRIL–JUNE: Boeing Starliner crewed test flight

JULY: Vulcan Centaur maiden flight with Peregine lander

31 JULY: End of NASA's Juno mission

8 AUGUST: ESA's Solar Orbiter flyby of Venus

11 AUGUST: ESA/JAXA's BepiColombo flyby of Venus

14 SEPTEMBER: Prichal launch to ISS

14 SEPTEMBER: First Dream Chaser mission to ISS

OCTOBER: Crew Dragon mission on behalf of Axiom Space

1 OCTOBER: First flyby of Mercury by the BepiColumbo mission

1 OCTOBER: Russia's Luna-25 launch

21 OCTOBER: NASA's Lucy launch

31 OCTOBER: James Webb Space Telescope launch

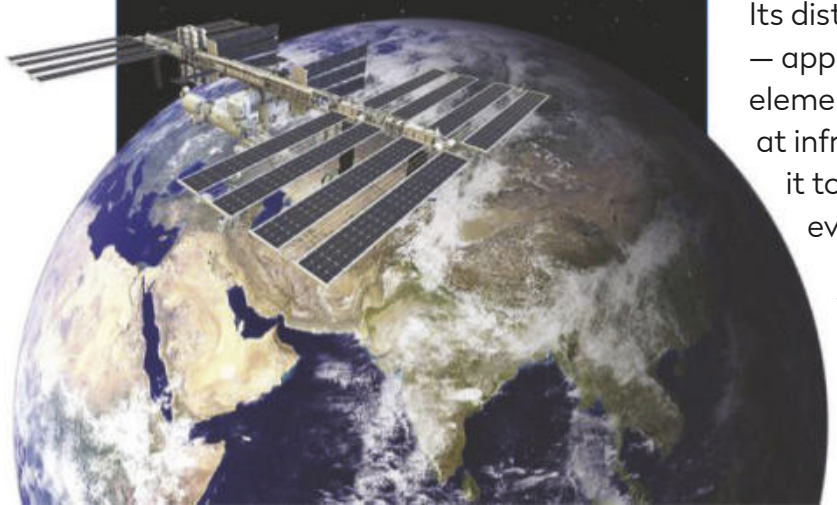
NOVEMBER: SLS (Space Launch System) maiden flight with Artemis-1

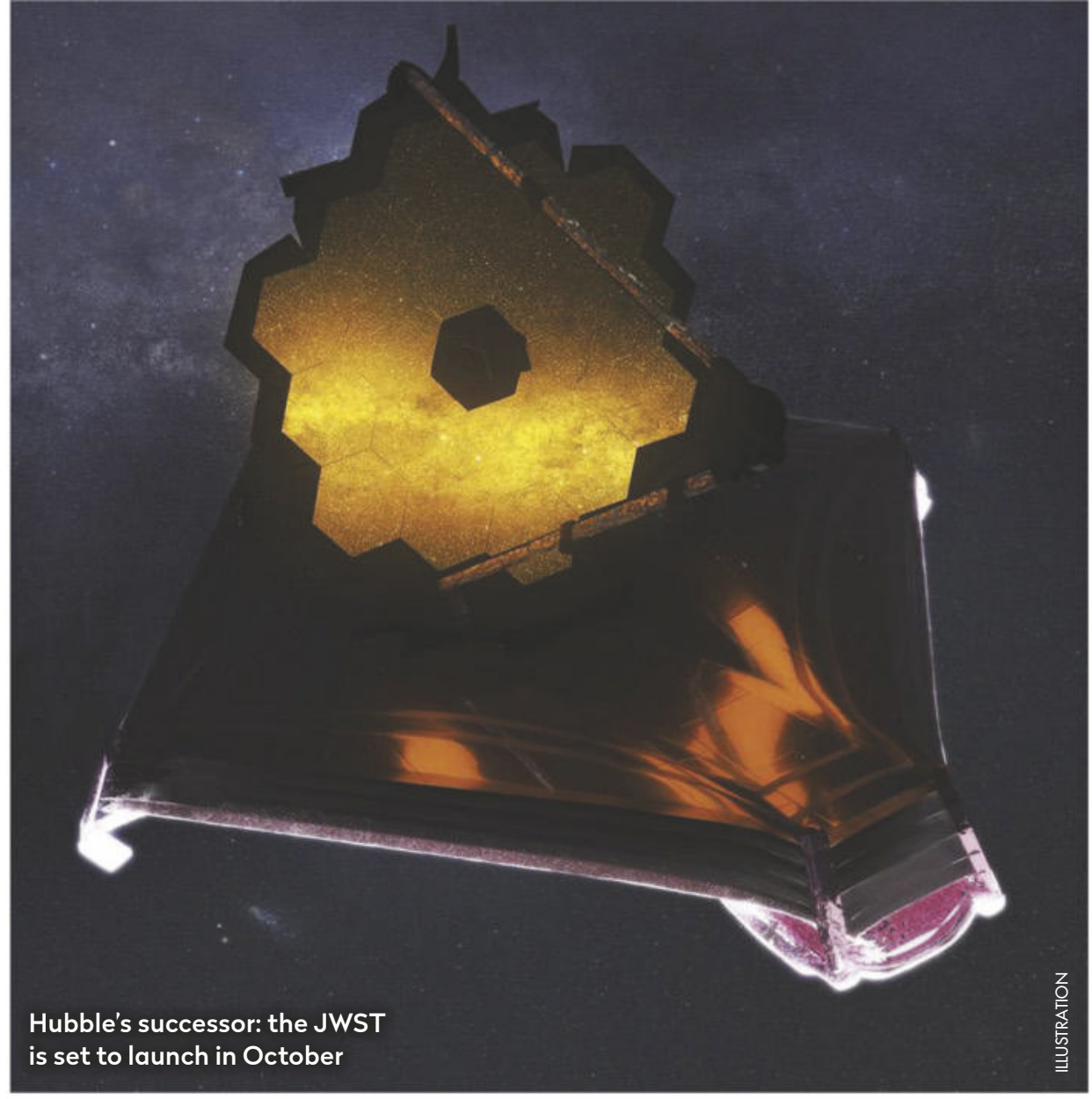
26 NOVEMBER: Solar Orbiter flyby of Earth

DECEMBER: First crewed flight of India's Gaganyaan spacecraft

LATE: Crew Dragon mission to ISS

LATE: Long March 5 launch with China's Tianhe space station module





Hubble's successor: the JWST is set to launch in October

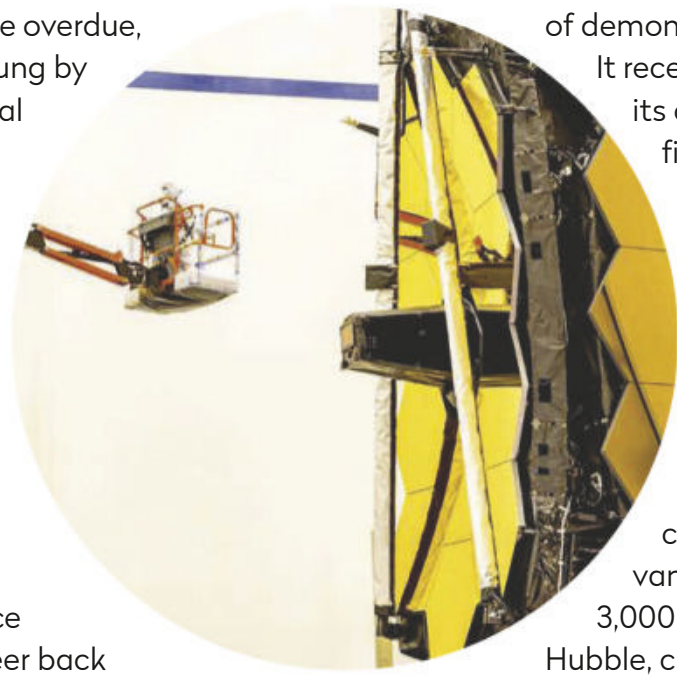
ILLUSTRATION

James Webb Space Telescope

After years of delays, could 2021 finally see the launch of the biggest ever space telescope?

More than a decade overdue, repeatedly hamstrung by intractable technical difficulties and billions of dollars over budget, the James Webb Space Telescope will finally rise from Earth atop an Ariane 5 rocket on 31 October 2021. Widely billed as the 'successor' to the Hubble Space Telescope, it will peer back to the dawn of time, a few hundred million years after the Big Bang, when the earliest galaxies began to form. But Webb could not look physically more unlike Hubble if it tried. Its distinctive — monstrous, even — appearance, with 18 hexagonal mirror-elements afford it unparalleled sensitivity at infrared wavelengths. And this allows it to view objects far more ancient than even Hubble can.

Launching aptly on Halloween, Webb has battled a multitude of demons over the years. It received praise for its capabilities and fierce derision for its insatiable guzzling of NASA funds. It was even labelled "the telescope that ate astronomy". But as it looks deep into the cosmos from a vantage point around 3,000 times higher than Hubble, chilled to –220°C to keep its sensitive detectors running at their optimum level of performance, its $10 billion price tag promises to make Webb worth its own weight in gold-coated beryllium.



Grand design: a technician is dwarfed by the main mirror of the JWST

ADRIANA MANRIQUE GUTIERREZ/NASA ANIMATOR, NORTHROP GRUMMAN

Ben Evans writes about space exploration. He is author of several books on the history of spaceflight

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Starry-night surprises: we guide you through the top sights to enjoy with your first telescope

Christmas night STARGAZING

A first-time telescope user's guide

Did Santa deliver a new telescope for Christmas? **Stuart Atkinson** gives some ideas about what to see with it when you take it out for the first time

Despite increasing levels of light pollution – around us and shining down on us from orbit – interest in the night sky has never been greater. Aside from the difficulties of the past year, many people have discovered the joy of looking up at the night sky for the first time, and many of them will have asked for a telescope this Christmas. That's not new; every year, as the Sun sets at the end of Christmas Day, turkey-stuffed newcomers to the hobby eagerly unpack their new telescopes and head outside hoping to come face to face with the beauty of the Universe and maybe even become the next Brian Cox or Patrick Moore. Maybe this year you count yourself among them.

However, as new telescope owners stand there beneath the winter sky, with their wacky Christmas jumpers hidden beneath thick coats and mighty Orion staring down at them, many may be disappointed – especially if the expectation was to see breathtaking views through their new telescope as good as the Hubble and Voyager images printed on its box. The actual night sky itself might be against them, too; they might want to see Saturn's rings, or the ice caps of Mars, but those planets might not be in the sky that night. With disappointment and disillusionment waiting for them in the dark as they set up their new telescope, there's a risk that this first night out with a telescope will be the last.

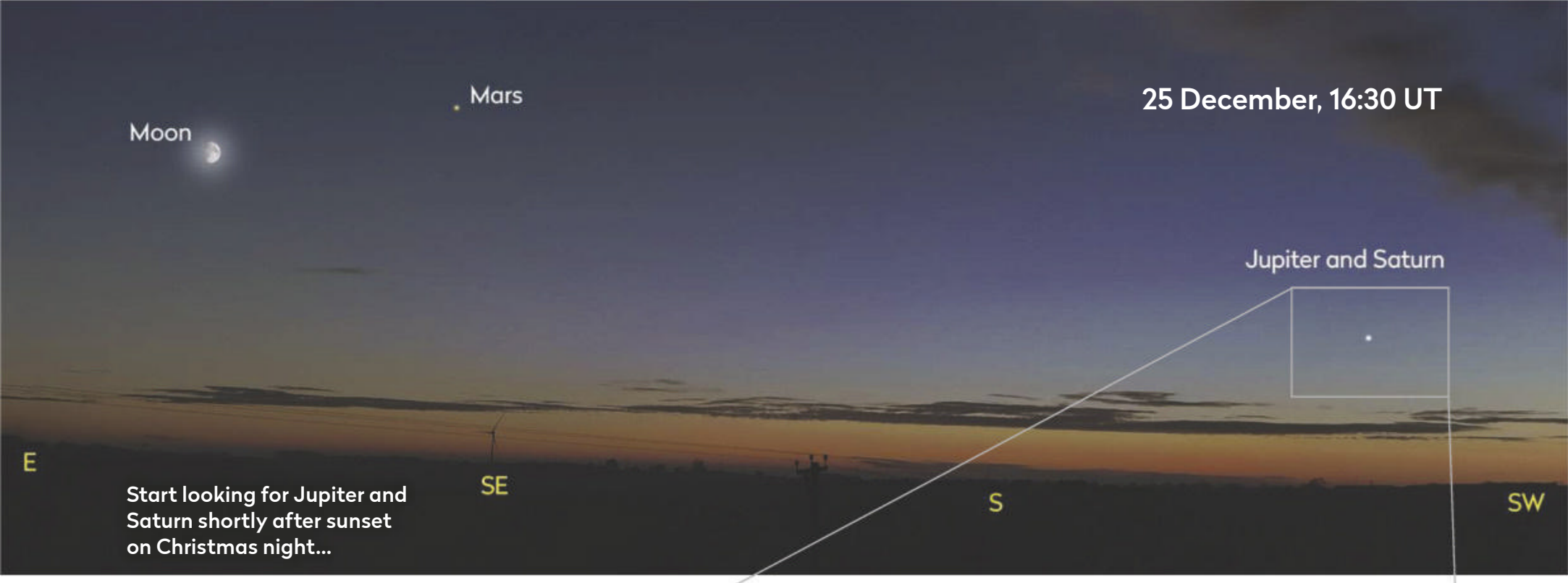
The good news is that it doesn't have to be that way; with the right guidance your first night with your new telescope can be a wonderful experience that will make you fall in love with the night sky. Indeed, your Christmas gift can inspire a lifelong interest.

This feature is that guide. We'll take you on a short tour across the Christmas night sky, helping you to munch your way through a celestial selection box of cosmic delights – things which will hopefully both inspire you and help you appreciate the reality of sky-watching with your new telescope. A gibbous Moon on the evening of 25 December will drown out the faint, misty light of many interesting objects, but that's okay, they'll still be there when the Moon has gone; there will still be many sights to see! ▸

NEED TO KNOW

Unfortunately, you can't just swing your telescope around the night sky at random and expect amazing things to appear in the view, and despite what some adverts would have you believe, your new telescope won't leap from one cool object to another all on its own. You're going to need some help to point it at the galaxies, star clusters and planets you've read about for so long. Throughout the feature you'll find tips to assist you with this...

ALEXXANDAR/ISTOCK/GETTY IMAGES



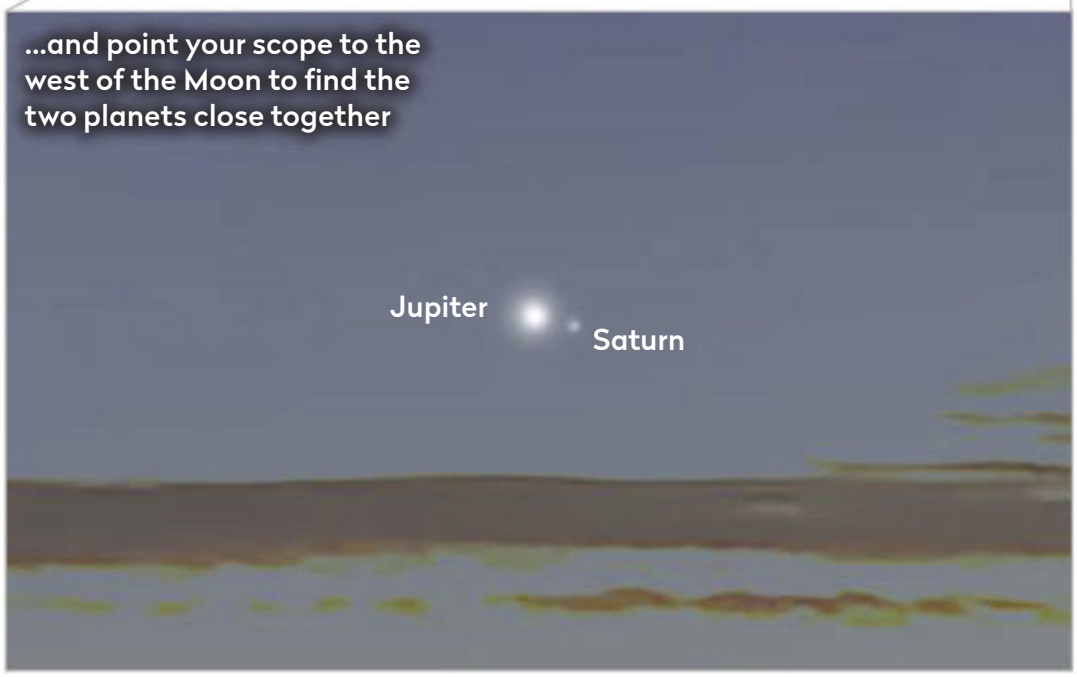
Jupiter and Saturn

It will be very tempting to swing your new telescope straight towards the Moon as soon as it's set up. After all, it will be the brightest and most obvious thing in the sky, and you'll have looked forward to seeing it through your own telescope for years. But the Moon will have to wait a little longer, as it's too close to being full. Instead, look to the west where you'll see two stars shining close together, low in the sky.

Those 'stars' are actually the two largest planets in our Solar System, Jupiter and Saturn, and they will be so close in the sky on Christmas night – just a Moon-width apart – that they will both be visible in your telescope at the same time. You'll have to start looking for them around 16.30 UT, not long after sunset, and you won't have long before they set.

Through your telescope you'll see both planets as tiny yellow-white discs, Jupiter's crossed by several darker cloud bands and Saturn's surrounded by those famous rings. Don't expect to see the rings as clearly as the Voyager or Cassini probes saw them; they will look very small through your telescope, but no less beautiful for that. If you zoom in on each planet individually with a high magnification eyepiece – one with a smaller number in mm (millimetres) on it, which indicates its focal length – you'll see two of Jupiter's huge family of moons shining close to it, one on either side of its disc, looking like tiny stars. Titan, Saturn's largest moon, will also be visible close to it.

As you look at this pair of planets it'll be fascinating to think that although they look close together in the sky they are actually almost five times further apart than the distance between the Sun and the Earth, and that Jupiter is so huge it could contain a thousand Earths with room to spare.



Mars

The Red Planet has fascinated us for centuries, and on Christmas night this enigmatic world, about half Earth's size, will be conveniently placed to the right of the Moon, making it very easy to find. Seen from a distance of 126 million km, Mars won't be as jaw-droppingly dramatic in your new telescope's eyepiece as it looks in photos you've seen in books and magazines, but it will still be fascinating to observe, and high magnifications should reveal one of its ice caps and perhaps even tantalising hints of markings on its ruddy surface. You'll also see that Mars looks more orange than red, despite its 'Red Planet' name.

All being well, NASA's Perseverance rover will land on Mars on 18 February 2021, to look for evidence of past Martian life in Jezero Crater.

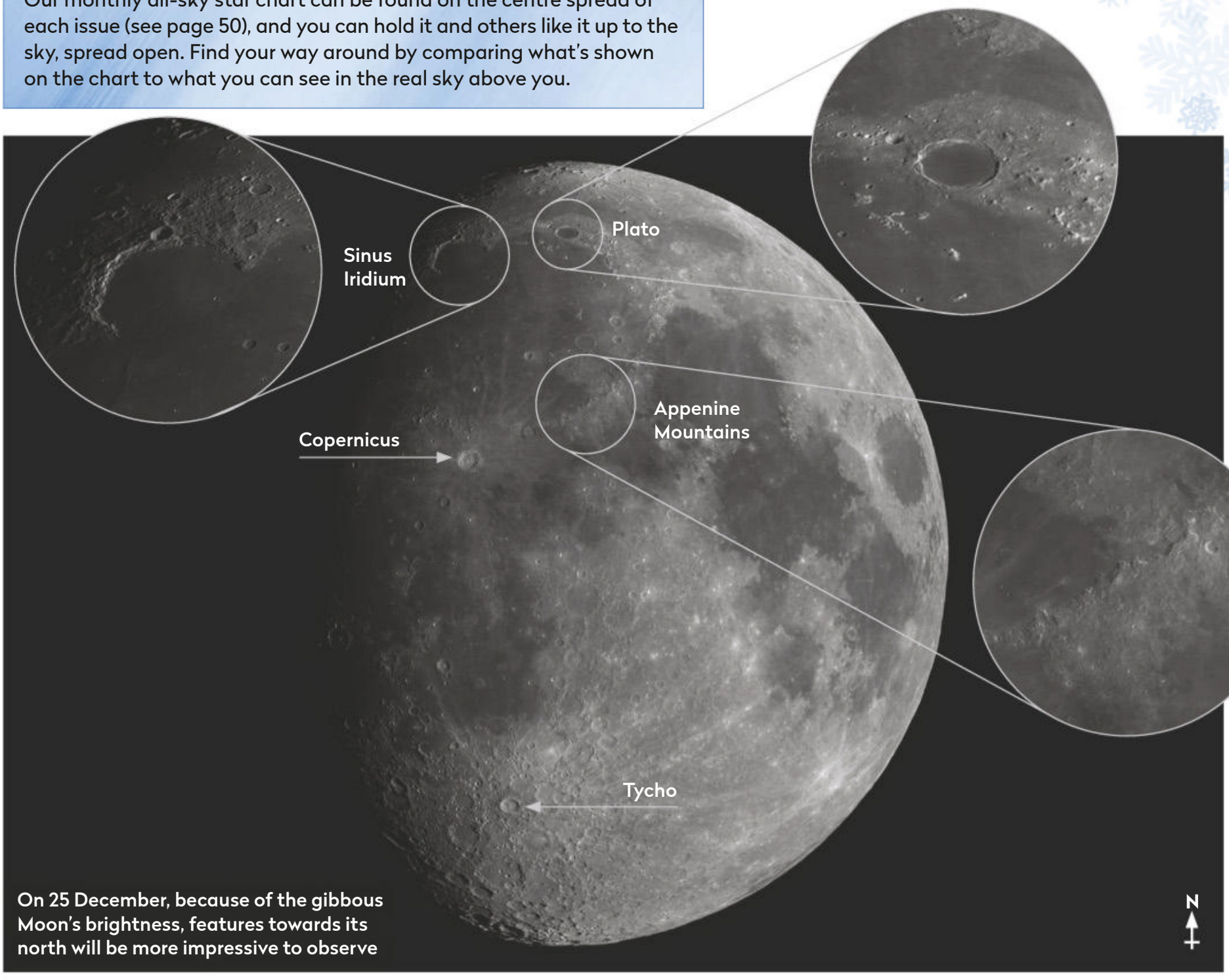
CHARTS BY PETE LAWRENCE

RECOMMENDED BOOKS

There are many great books to help a new telescope owner find their way around the sky. *Turn Left At Orion* by Guy Consolmagno is a classic that has helped beginners over the years. Helpfully, it's full of easy-to-use star charts that will show you exactly where to find many deep-sky objects. It's illustrated with realistic sketches instead of photographs to show you what you will actually see through your eyepiece. There are also several paperback-sized guides to the sky for the year ahead, such as Collins' *Stargazing*, which features monthly charts and information about astronomical events, and of course our own special issue publication, *The Astronomer's Yearbook 2021*.

USING A STAR CHART

Star charts are maps of the night sky, and you will find them in this magazine and astronomy books and online too. At first glance they can look confusing, covered with dots, lines and bizarre symbols that look like they should be in a Hogwarts spell book from *Harry Potter*, but they are easy to use once you get started. Scattered through you'll find the constellations, star clusters, galaxies and nebulae are represented by different coloured shapes, each one labelled to help you identify it. Our monthly all-sky star chart can be found on the centre spread of each issue (see page 50), and you can hold it and others like it up to the sky, spread open. Find your way around by comparing what's shown on the chart to what you can see in the real sky above you.



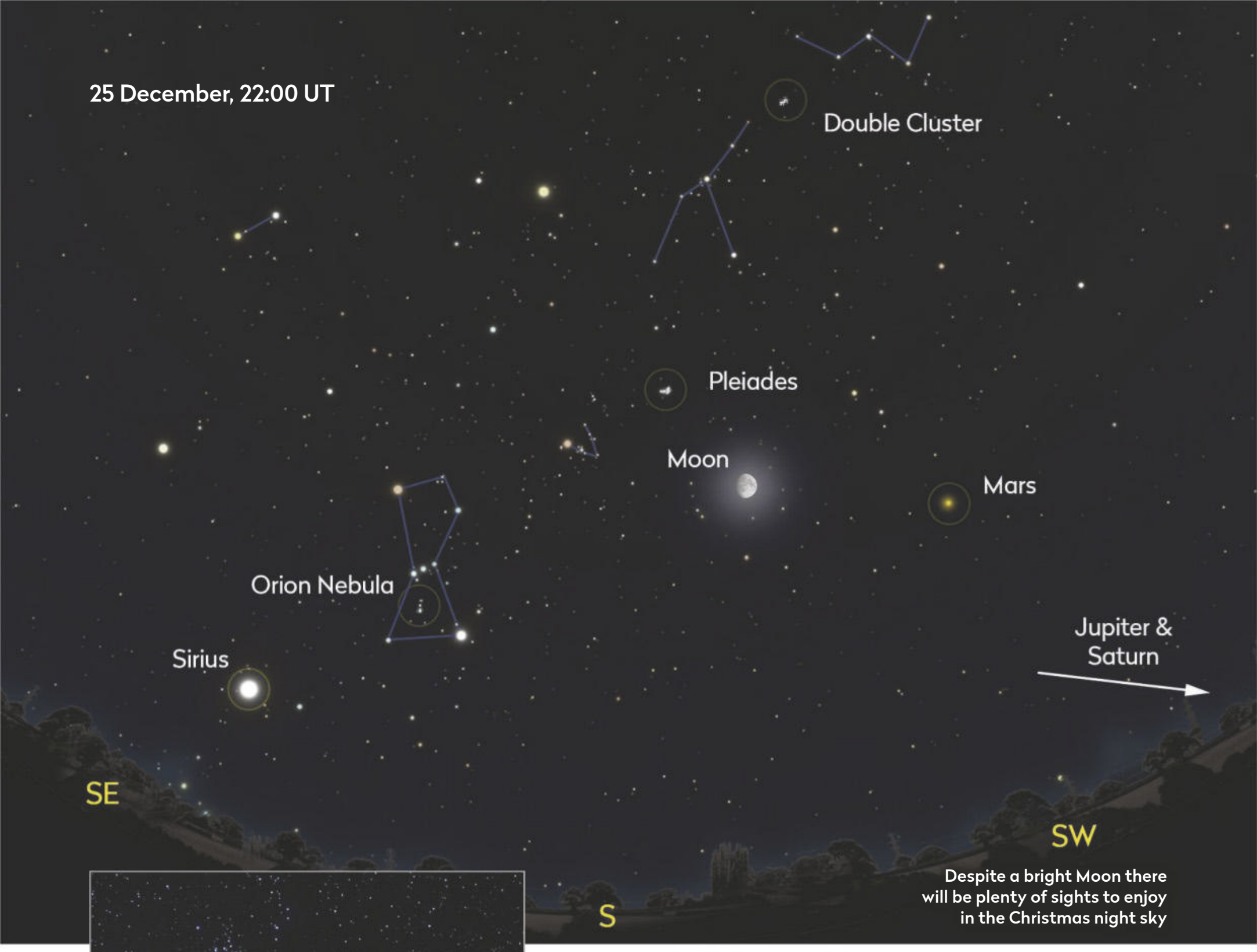
On 25 December, because of the gibbous Moon's brightness, features towards its north will be more impressive to observe

The Moon

Covered with thousands of dramatic craters and criss-crossed by ranges of towering mountains, the Moon is the most obvious first target for every owner of a new telescope, but on Christmas night this year it will be close to full, so only a few of those features will really 'jump out' in an eyepiece. However, towards the 'top' of the Moon the dark-floored crater Plato and the crescent-edged bay Sinus Iridium will both be fascinating sights.

At high magnification some detail will be visible along the terminator – the line between the illuminated and unilluminated parts of the Moon's face, but your best views will be through low magnification eyepieces (you guessed it, ones with a larger number in mm on them). These will clearly show the Moon's maria – its dark seas of ancient, frozen lava – its rugged, bright highlands and the bright curve of the jagged Appenine Mountains at its centre. You'll also be able to see long silvery rays of dust and debris stretching away from the giant craters Copernicus and Tycho.

As you gaze at our nearest neighbour through your new telescope, try to imagine the excitement that will accompany the arrival of the first Artemis landing, later this decade, when the first woman astronaut will walk on the surface of the Moon. ▸



Despite a bright Moon there will be plenty of sights to enjoy in the Christmas night sky

The magnificent Orion Nebula may not be at its very best tonight, but it's always worth a look

The Orion Nebula

Beneath Orion's famous Belt, in the centre of his Sword, lies M42, the Orion Nebula. This is a glowing cloud of dust and gas, a 'stellar nursery' 1,400 lightyears from Earth, where stars are being born. It's one of the most beautiful objects in the sky and is visible to the naked eye – when that sky is dark.

M42 will rise in the east at around 18:00 UT, as Jupiter and Saturn are setting in the west, but Christmas night's bright Moon, shining to Orion's upper right, will wash out the nebula's faintest detail and the subtle grey-green colour of its wispy structures. However, the brightest central regions will still shine through the moonlight and the Trapezium, a tiny quartet of pinprick stars at its heart, will be seen easily with those higher magnification eyepieces.

NIGHT SKY SMARTPHONE APPS

Many astronomers – experienced and absolute beginners – use their mobile phones and tablets to help them find their way around the sky. There are many astronomy apps available which use GPS to pinpoint the user's location on Earth and show them what they can see in the night sky above at that time, or any other date or time they choose. Try *Sky Safari* (1), a paid planetarium app with a huge database of objects; *Stellarium Mobile Free* (2), a planetarium app with an attractive, realistic view of the night sky; or *Heavens Above* (3), which will tell you when the International Space Station and satellites will be visible from your location. Using them is really simple: just load up the app, hold your phone or device up to the sky, and a chart appears on screen showing you what you can see. The constellations, stars and planets are all labelled, and as you sweep your device around the sky the app tells you what you're pointing it at. Apps also give information about rising and setting times, meteor showers and other astronomical events.

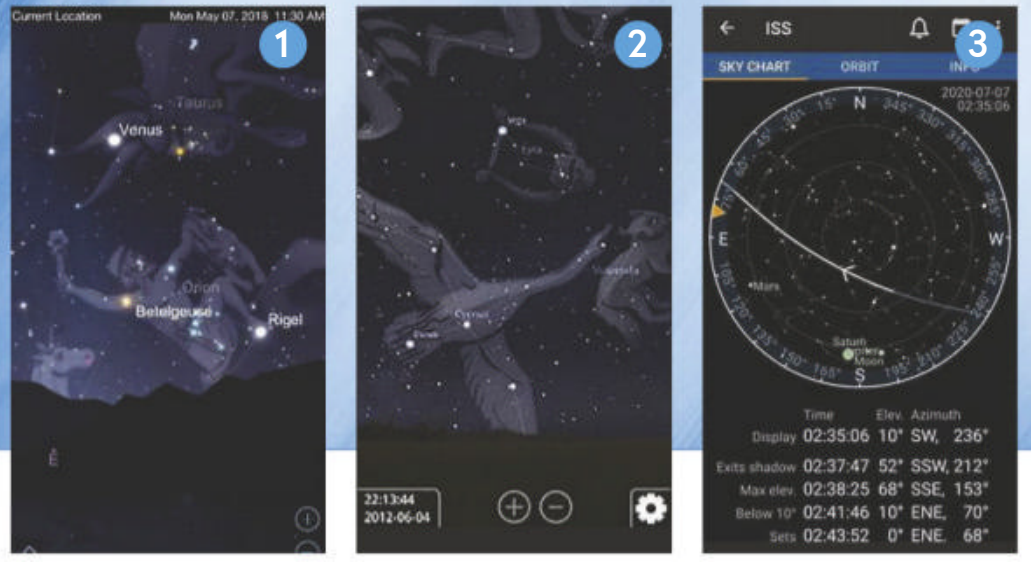


CHART BY PETE LAWRENCE, INGA-AV/ISTOCK/GETTY IMAGES, VIKTAR/ISTOCK/GETTY IMAGES, BRIGHTSTARS/ISTOCK/GETTY IMAGES X 2, ROBERT LANE/ISTOCK/GETTY IMAGES

The Pleiades


The Pleiades open cluster appears like a celestial treasure trove, full of glittering stars

Probably the most famous star cluster in the sky, the Pleiades will be a real "Wow!" sight on Christmas Night, despite the bright Moon nearby. At 430 lightyears from Earth, the Pleiades – also known as 'The Seven Sisters' because of its seven stars that are visible to the naked eye – is an easy observing target.

Through your new telescope its myriad stars will glitter like tiny diamonds at low magnification, looking like a miniature Plough, and higher magnifications will fill and even overflow your field of view with a bewildering number of stars, sparkling like chips of shattered ice. When the Moon has gone and you look at the Pleiades on a dark night you'll see how astonishingly beautiful it is, so be patient!

The Double Cluster


With too many stars to count, the Double Cluster will be a stunning sight through a telescope

Lying between the W of Cassiopeia and the upside-down Y of Perseus, this deep-sky object will be a stunning sight on Christmas night. Even your new telescope's lowest magnification eyepiece will give you a glorious view of these clusters, looking like two piles of glittering dust shining side by side; while higher magnification will reveal them as containing too many stars to count. Finding and observing the Double Cluster helps newcomers understand one of the basics of astronomy; just because two objects look close in the sky doesn't mean they are – one of the clusters is much further away than the other.

Sirius

Finally we come to Sirius, the brightest star in the sky. It's easy to find – Orion's Belt points straight down to it – and on frosty winter nights it looks like a finely-cut diamond flashing above the treetops. You might think that if you swing your new telescope towards it, Sirius will look bigger, but it will still just be a point of light. So why bother? Because through your telescope the star's twinkling will be greatly enhanced, and you'll see it flashing and sparkling like crazy in red, blue and gold; it's a lovely sight to see.

Stuart Atkinson is a lifelong amateur astronomer, public outreach educator and author of nine books on astronomy and spaceflight

DARK ADAPTED VISION


Let your eyes adjust to the darkness and you'll see so much more

Once it's all set up you'll be impatient to sweep your new telescope around to point at something on our list and have a good look. However, you'll need to wait just a little longer, because even if you and your new instrument are ready to begin touring the Universe, your eyes won't be. If you go outside and look through your telescope right away your eyes won't have had time to get used to darkness, and the view will be disappointing. But after a period of 'dark adaptation' your eyes will have gone through both physical and chemical changes that will enable them to gather more faint starlight, and the views through your scope will be better. So be patient; after half an hour of adapting your vision to the dark you'll see many more stars in the Pleiades, and more detail on Jupiter and in the Orion Nebula than you would have done if you'd just looked at them straight away.

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

JANUARY 2020

EVENING PLANETS

Before they disappear behind the Sun, enjoy Jupiter and Saturn's dramatic line-up with Mercury

NEW YEAR'S METEORS!

Get the best views of January's Quadrantids

HIDDEN BY THE MOON

Observe the Moon's occultation of open cluster M35 in Gemini

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Morning Venus and the waning crescent Moon
- Get to know the lunar crater Gassendi
- Can you spot the Horsehead Nebula?

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

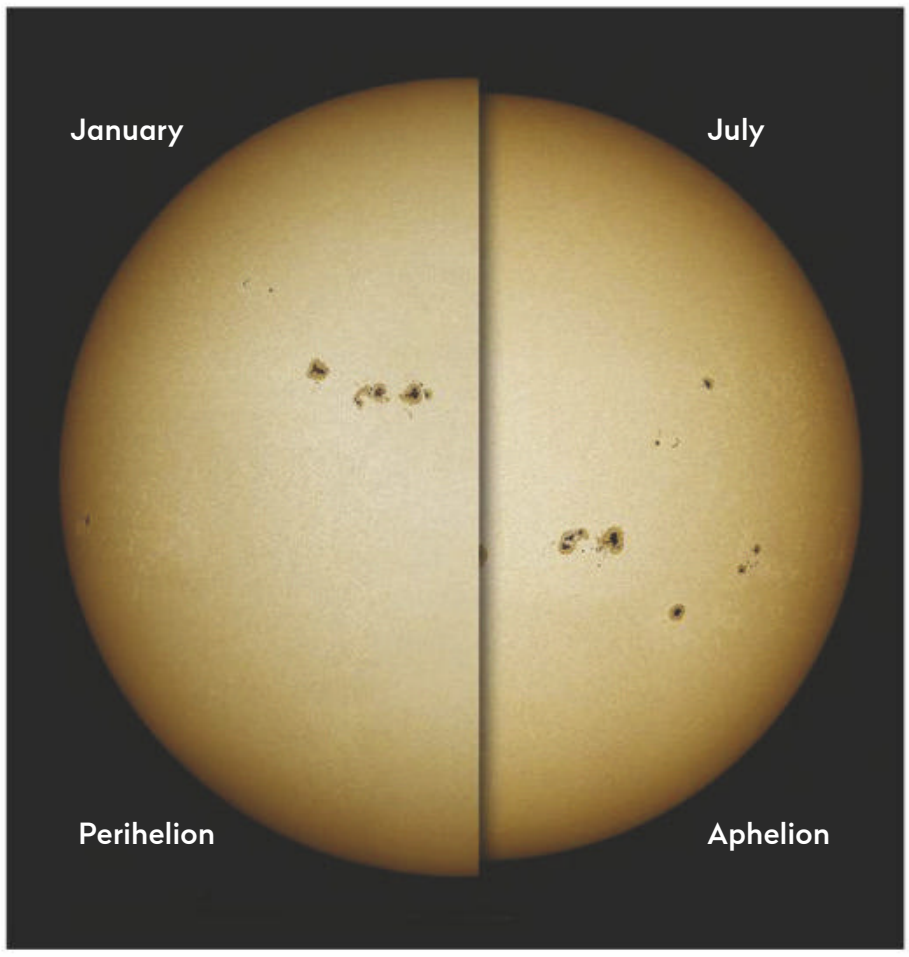
JANUARY HIGHLIGHTS

Your guide to the night sky this month

Friday 1

A 96%-lit waning gibbous Moon lies 2.3° northwest of the Beehive Cluster, M44, at 06:00 UT, just before the onset of dawn.

A telescopic view of Mars at 19:00 UT shows Solis Lacus, the 'Eye of Mars'.



◀ Saturday 2

Earth is at perihelion at 08:50 UT, the point in our planet's orbit when we're closest to the Sun. At this time we're 147,093,163km away, compared to 152,100,527km at aphelion (most distant) on 5 July. As a consequence, the Sun's apparent diameter is at its largest for the year today.

Friday 8

Through a telescope, Mars is shrinking. This evening its 9.7 arcsecond disc shows the zero-longitude marker, Sinus Meridiani on the planet's central meridian at 18:00 UT.

Saturday 9

Located at a very low altitude above the southwest horizon from 30 minutes after sunset, mag. –0.8 Mercury, +0.9 Saturn and –1.8 Jupiter form a tight triangle less than 3° across.

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◀ Monday 11

Mag. –3.8 Venus lies 6.7° east of a waning crescent Moon, 70 minutes before sunrise over a southeast horizon.

Mercury, Saturn and Jupiter form a triangle over the southwest horizon, 30 minutes after sunset.

Thursday 14

Mag. –1.8 Jupiter, –0.8 Mercury and +0.9 Saturn are joined by a thin 2%-lit Moon, 4.5° southeast of Mercury. You'll need to be quick though as all four objects are visible for a short time, very low above the southwest horizon 35 minutes after sunset.

Wednesday 15

A telescopic view of Mars this evening at 18:00 UT will show the large V-shaped albedo feature Syrtis Major on the central meridian. The round form of Hellas will be visible south of Syrtis Major, to the north of the south polar cap.

Thursday 21

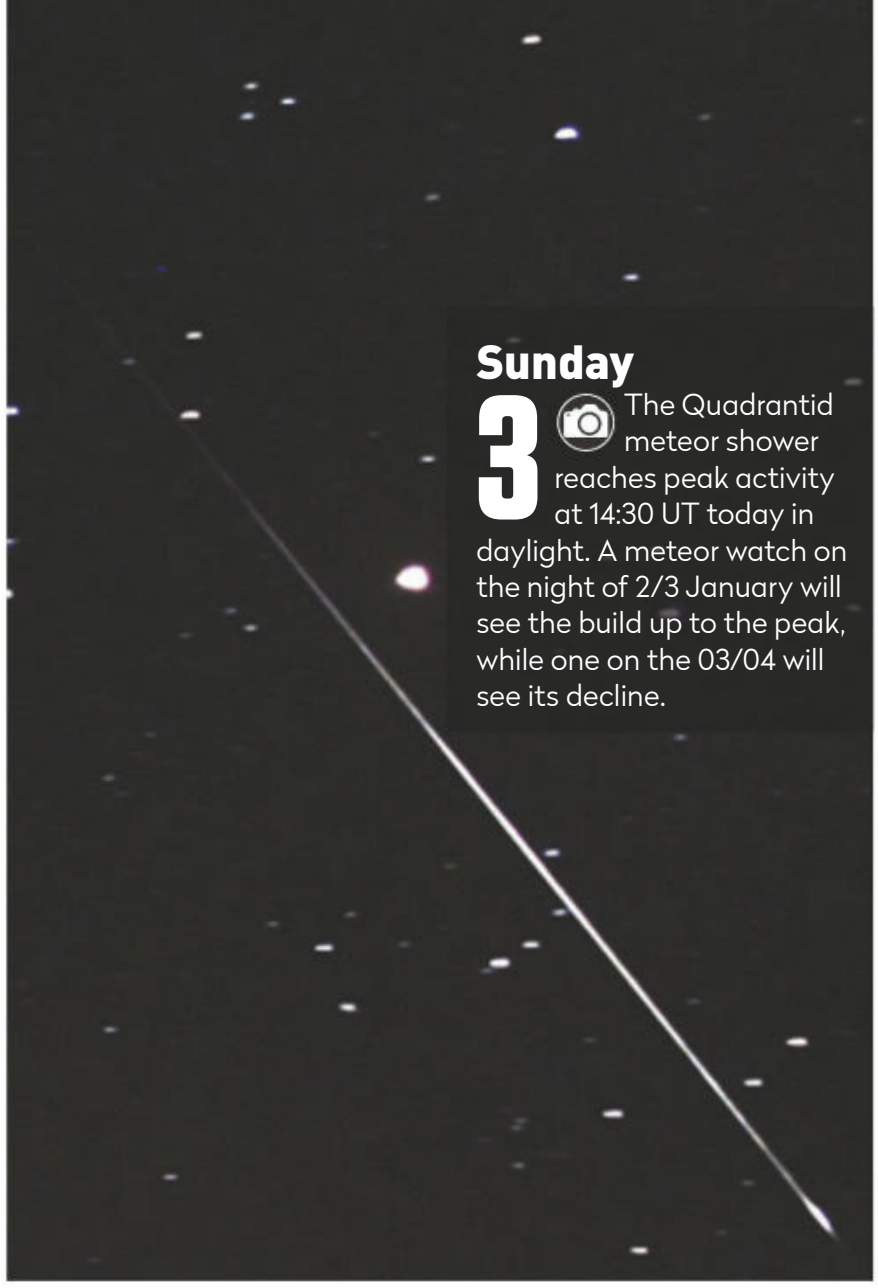
Mag. +0.2 Mars is 6.5° northwest of this evening's 58%-lit waxing gibbous Moon at 18:30 UT.

Friday ▶ 22

Through a telescope, Mars is now showing an 8.5 arcsecond disc. At 18:00 UT, as the sky darkens, the twin prongs of Sinus Gomer are visible centrally on the disc.

Family stargazing

Mercury is elusive; despite sometimes appearing bright, the planet never leaves the bright sky near the Sun and this makes it tricky to see. The best spotting times are after sunset or before sunrise, depending on where the planet sits relative to the Sun. This month there's a good opportunity for post-sunset viewing from 8 January through to the month's end. Put safety first and ensure the Sun has set before looking. Then, from a location with a flat west-southwest horizon, make your attempt. The planet passes Jupiter and Saturn between 9-12 January. **www.bbc.co.uk/cbeebies/shows/stargazing**



Sunday
3 The Quadrantid meteor shower reaches peak activity at 14:30 UT today in daylight. A meteor watch on the night of 2/3 January will see the build up to the peak, while one on the 03/04 will see its decline.

Wednesday
6 A look at the 51%-lit (last quarter) Moon through a telescope this morning will show the Straight Wall, Rupes Recta. Together with the curving Stag Mountains at the southern end, this forms a clair-obscur effect known as the Cutlass.

Sunday
10 A 10%-lit waning crescent Moon sits 5° from mag. +1.0 Antares, low above the southeast horizon at 06:40 UT.

The low altitude planetary conjunction between Mercury, Jupiter and Saturn tightens up further this evening.

◀ Thursday
16 This evening's 13%-lit waxing crescent Moon is showing a libration which favours the northeast limb. Features such as Mare Humboldtianum (circled) will be visible.

Wednesday
20 The shadow effects which produce the Lunar X and V will occur this evening, with peak visibility just after 19:00 UT.

Mag. +0.2 Mars sits 1.6° north of mag. +5.8 Uranus this evening.

Sunday
24 Mercury reaches greatest eastern elongation this evening, when it will appear separated from the Sun by 18.6°. The mag. –0.4 planet will remain above the southwest horizon for nearly two hours after sunset.

Friday
29 Jupiter is in conjunction with Sun, after which it'll be a morning object.

Monday
25 This evening's bright 91%-lit waxing gibbous Moon occults the southern two-thirds of the mag. +5.5 open cluster M35, starting around 23:00 UT.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

LUNAR HIGHLIGHTS

BEST TIME TO SEE:
20 January, around 19:00 UT for the Lunar X and V; 25 January, from 23:00 UT for the M35 occultation

The Moon is a popular target for January; a bright, easy to locate object if you have been lucky enough to receive a new telescope for Christmas. It's also a popular photographic target, easily bright enough to register on the continually evolving imaging technology found within modern smartphones.

The Moon isn't appreciated by everyone and for hunters of the more diffuse objects in the night sky – objects such as nebulae, comets and galaxies – it's regarded as a bit of nuisance. This is especially true at this time of year, because the larger, brighter and generally more intrusive phases of the Moon ride higher in the sky.

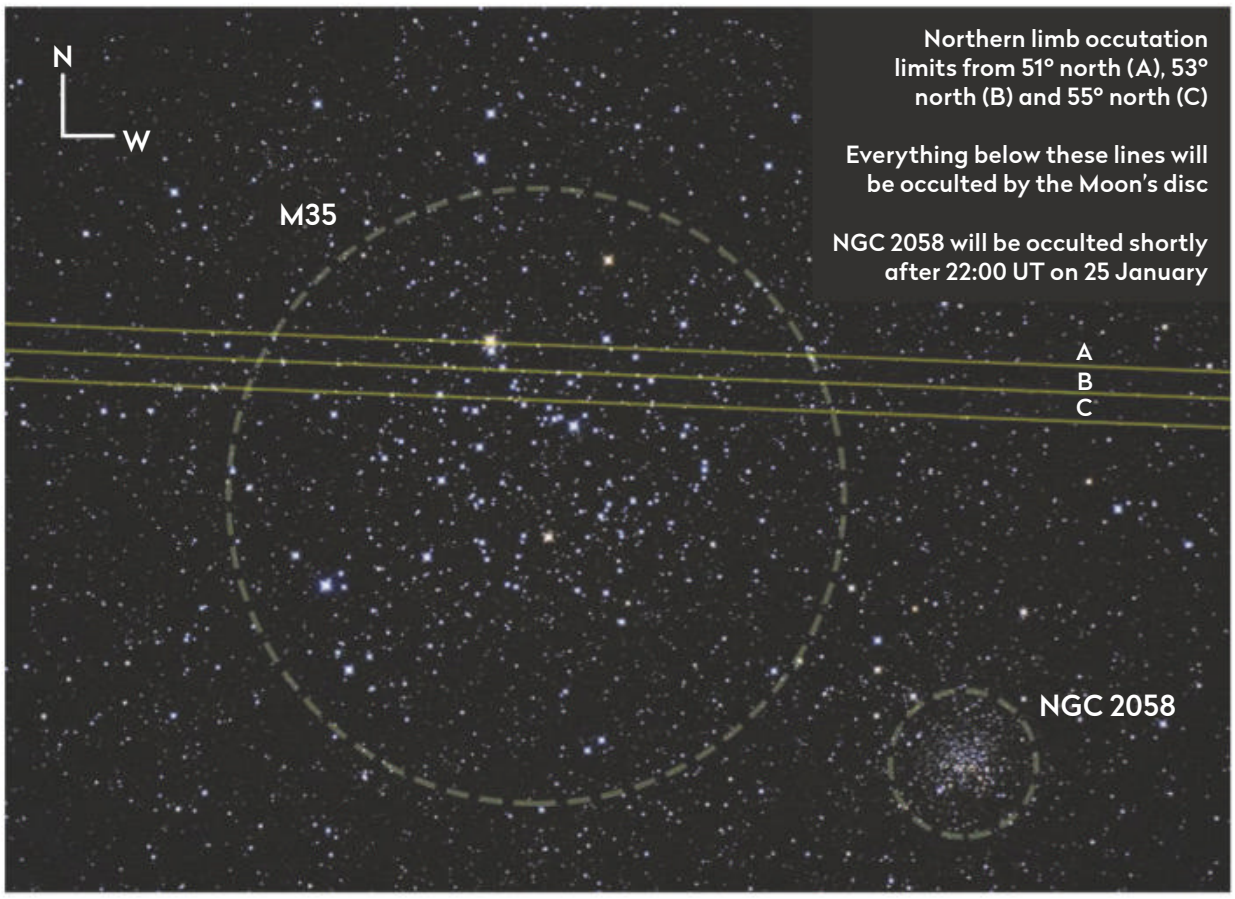
Despite its apparent brilliance, the Moon has a relatively low reflectivity or albedo. Its surface reflects just 12 per cent of incoming light, equivalent to the reflectance of dull asphalt! Just imagine how bright it would appear if it had a significantly higher albedo.

If you can forgive the Moon its glare, there's plenty to see on its surface, something we cover in detail every month in our 'Moonwatch' section (see page 52).

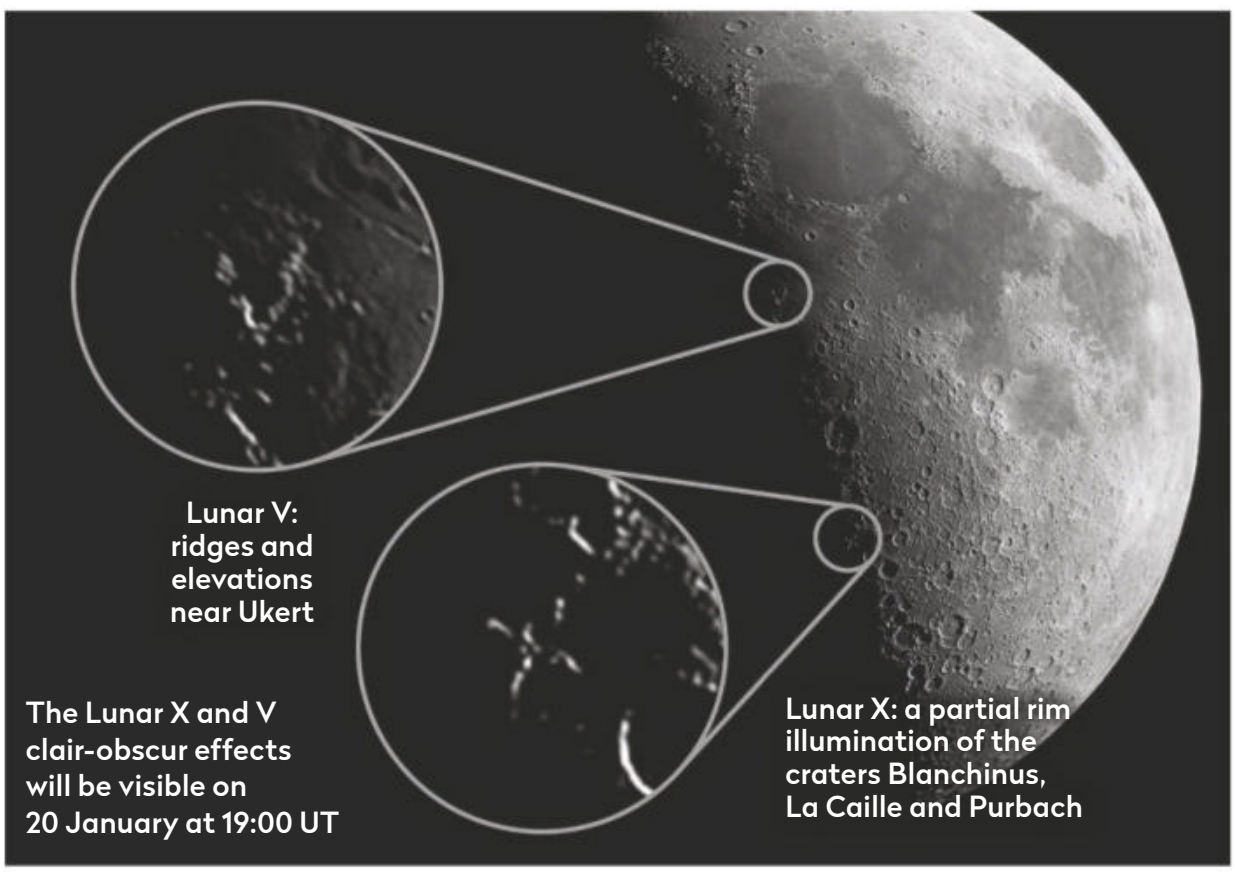
In addition, transient events such as occultations sometimes take place. A great example occurs on 25 January when the Moon appears to move in front of the southern two-thirds of the open cluster M35 in Gemini, an event we've reported on over recent months too. The 25 January event is particularly well-placed and suits viewing with a small telescope at low power.

The Moon will start to cover the cluster's stars from 23:00 UT and with magnification this should be fairly easy to see as long as the sky is fairly transparent. It's the dark, leading edge of a 91%-lit waxing gibbous Moon which leads the occultation and this will make things a little easier. The event draws to a close around 01:00 UT on 26 January.

Other popular events requiring a bit of luck with timing are so-called clair-obscur effects. These occur when the Sun is in a particular position relative to a certain feature on the Moon's surface. The way the feature's shadows appear can cause a visual effect that makes the scene resemble something familiar. Two famous effects are known as the Lunar X and V. Here, the letters 'X' and 'V' appear on the Moon's terminator, the dividing line between lunar day and night. The effects can be seen on the evening of 20 January, reaching peak visibility around 19:00 UT. Roughly speaking, the Lunar X will appear a quarter of the way up the Moon's terminator from the southern point, the V appearing roughly at the terminator's mid-point.



▲ **The Moon will begin the occultation of the open cluster M35 at 23:00 UT on 25 January**



ALL PICTURES: PETE LAWRENCE

Evening planets

BEST TIME TO SEE: As indicated

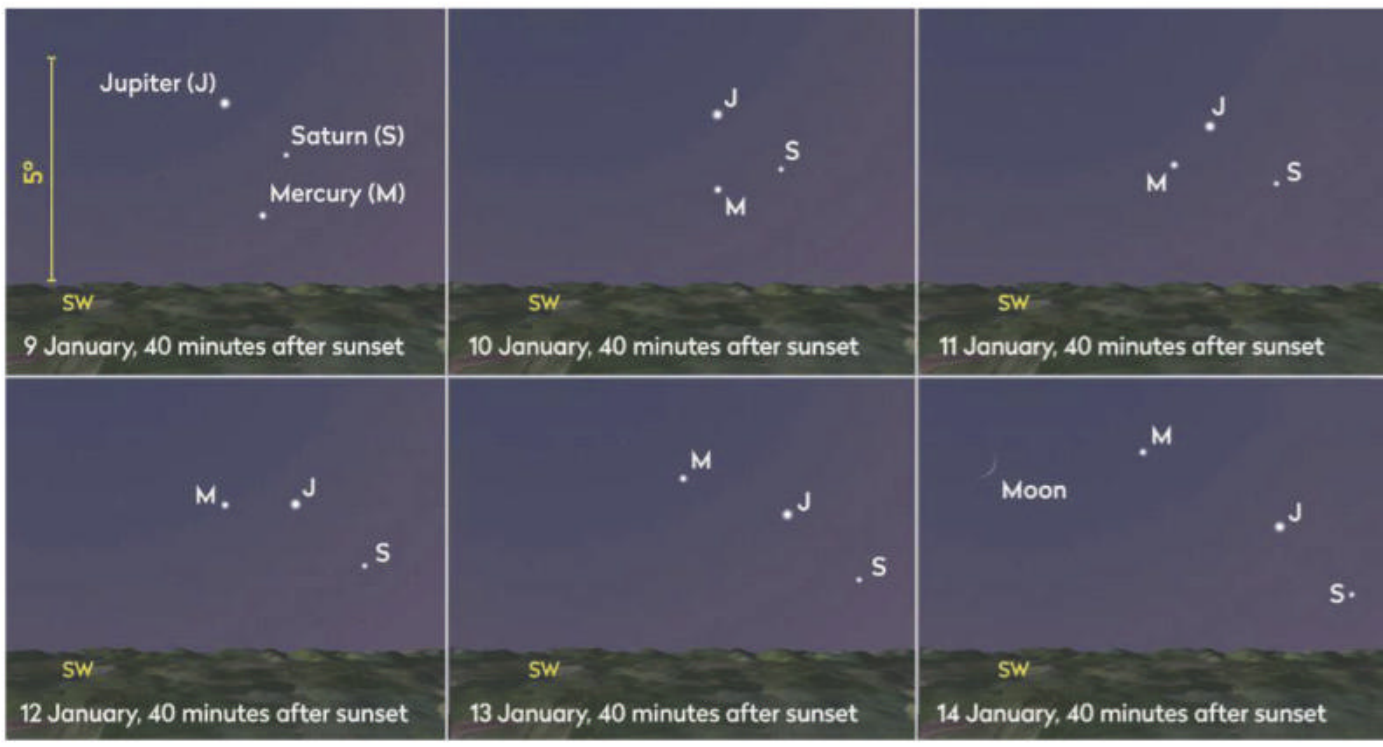
Following last month's Great Conjunction, evening planets Jupiter and Saturn remain close during January but their visibility degrades as they slip ever closer towards the Sun, Saturn reaching solar conjunction on 24 January. This date marks Saturn's transition from the evening sky into the morning sky.

Last year, Jupiter lay west of Saturn. After the Great Conjunction, which took place on 21 December 2020, the planets have swapped sides and Saturn is now lying west of Jupiter. Jupiter is the brighter of the pair at mag. –1.8 and is the first to appear after sunset, typically visible from around 30 minutes after the Sun has dropped below the horizon. Mag. +0.9 Saturn is still pretty close at the start of January and should be fairly easy to pick out as the sky continues to darken.

From 7 January, the pair are joined by Mercury. Located closer to the Sun on 7 January, Mercury has the advantage of being relatively bright itself at mag. –0.9. From 9 January until 13 January, Mercury, Jupiter and Saturn remain close, forming an ever-changing geometric pattern as the swifter inner planet appears to zip past the lumbering gas giants. By 13 January, Mercury will still be bright at mag. –0.8.

On 14 January, Saturn will become tricky to spot unless you have a flat southwest horizon. On this date, Mercury, Jupiter and Saturn will be joined by a slender 2%-lit waxing crescent Moon. The Moon will be on par with the altitude of Mercury, the higher of the three planets, and located 4.5° further to the southeast.

As Jupiter and Saturn are lost in the Sun's glare, Mercury continues to creep east towards a favourable eastern elongation on 24 January.



▲ Follow the ever-changing geometric patterns formed by the planets Mercury, Jupiter and Saturn after 9 January. They are joined by a waxing crescent Moon on 14 January

Quadrantids 2021

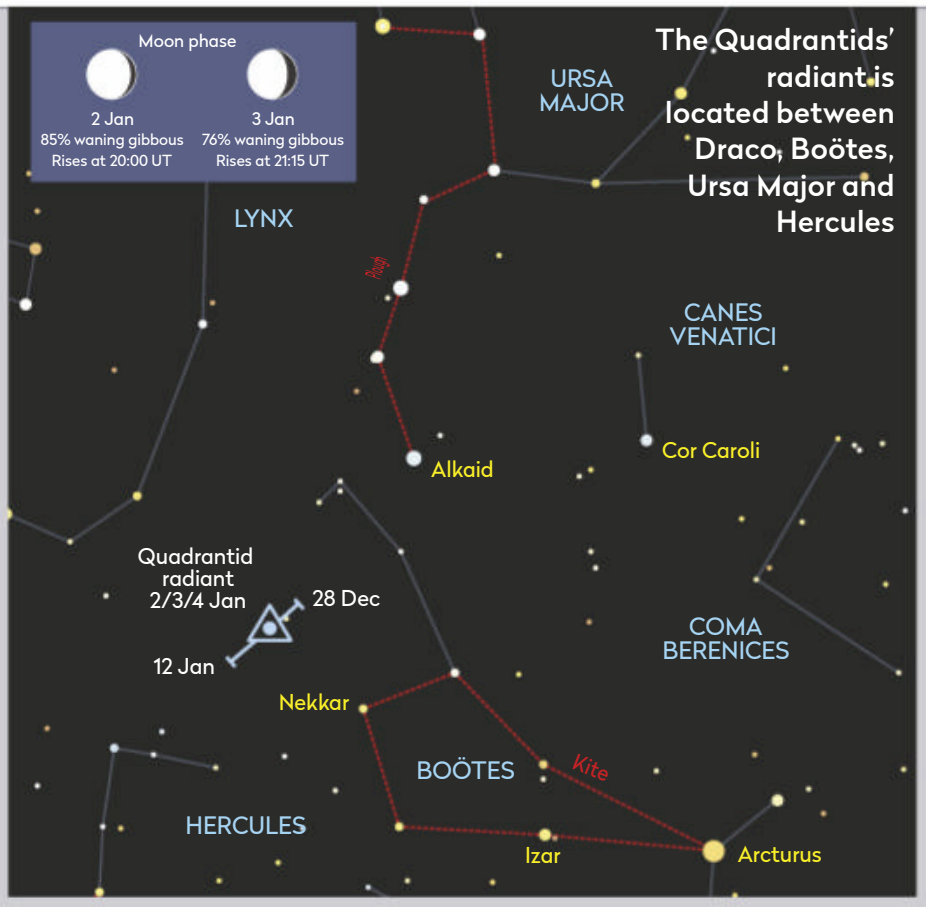
BEST TIME TO SEE: The nights of 2/3 and 3/4 January

The Quadrantids is the first of the major annual showers. These are swift meteors and the shower is expected to peak at 14:30 UT on 3 January. Consequently, the best time to look for Quadrantid meteors will be on the nights of the 2/3 and 3/4 January. A waning gibbous Moon will cause problems this year, its glare drowning out all but the brighter trails.

The Quadrantids' peak ZHR (zenithal hourly rate) is around 120 meteors per hour but can vary. The highest observed rates have approached 600 meteors per hour, while the lowest have dipped to just 60 meteors per hour. The ZHR figure is a normalised value used to allow comparison between meteor showers and doesn't represent what you'll actually see. The visual hourly rate is often significantly lower than the quoted ZHR and varies over the course of a night.

The Quadrantids peak is typically rather narrow at just a few hours wide. As the expected peak is roughly in the middle of the day on 3 January, it means remaining activity in the periods of darkness before and after the peak is likely to be rather low.

The shower's radiant is located in the region of sky between Draco, Boötes, Ursa Major and Hercules. It's a region that used to be occupied by the now defunct constellation Quadrans Muralis, the Mural Quadrant – hence the shower's name.



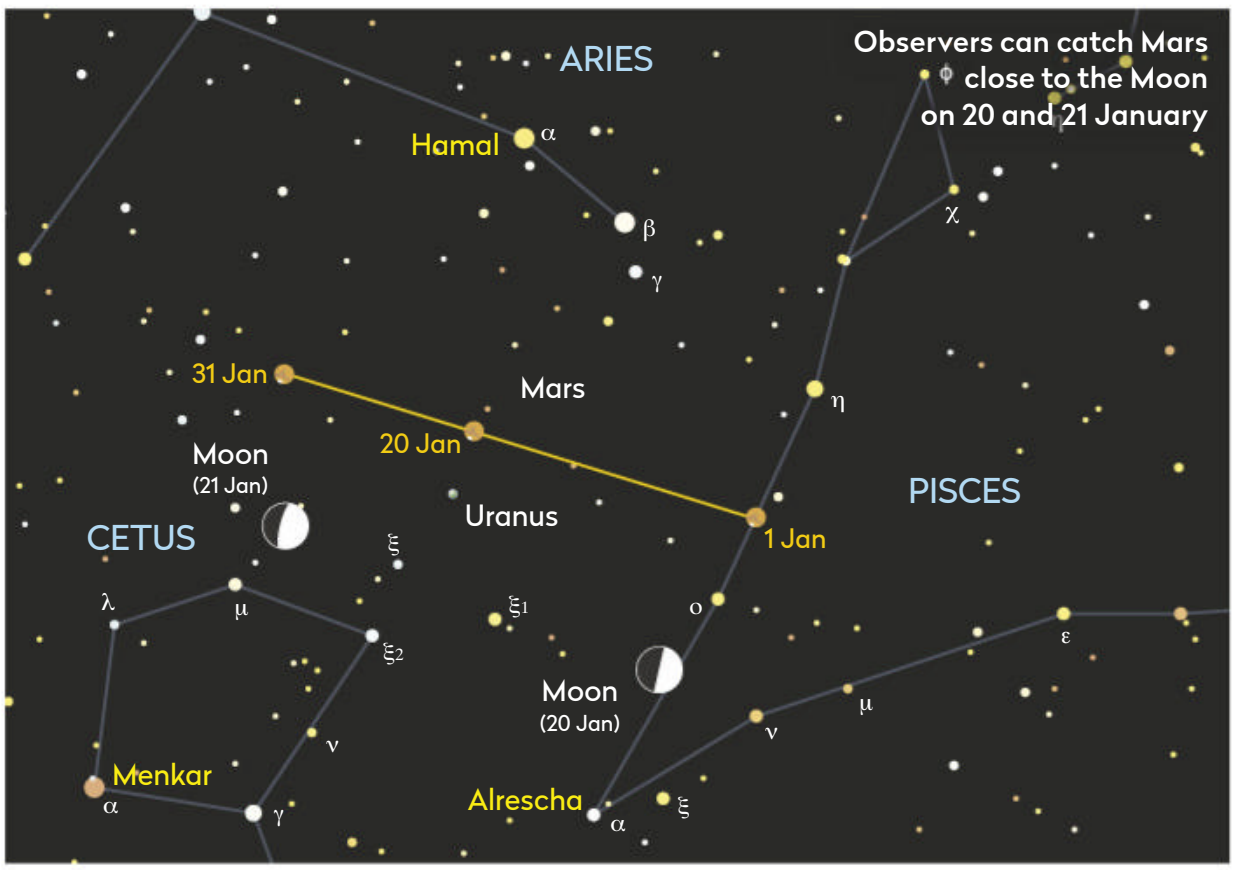
THE PLANETS

Our celestial neighbourhood in January

PICK OF THE MONTH

Mars

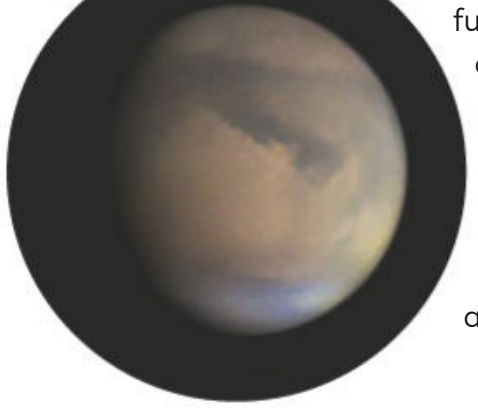
Best time to see: 1 January, 19:00 UT
Altitude: 48°
Location: Pisces
Direction: South
Features: Albedo markings, polar caps, weather
Recommended equipment: 150mm or larger



At the start of January Mars is well placed, reaching its highest position due south around 19:00 UT. From the centre of the UK this positions it 48° up. Through a telescope the mag. –0.2 planet shows a 10.4 arcsecond disc on 1 January, still large enough to show detail through an amateur telescope. At present the north polar hood (NPH) should be quite evident. This is an extensive cloud covering over the planet's north polar cap (NPC). The now rather depleted southern cap should also be visible as a small bright patch close to the planet's southern limb.

During January Mars will be showing a phase, appearing slightly less than 90%-illuminated. The Red Planet has an encounter with the first quarter Moon on the evening of the 20th, the Moon appearing 7.3° from the planet just before they set at around 00:30 UT on the 21st. Later, on the evening of the 21st, the now 58%-lit waxing gibbous Moon will lie 6.4° from Mars as darkness falls. On the evening of the 21st, mag. +0.2 Mars sits 1.7° north of mag. +5.8 Uranus.

As the month progresses, Mars moves east, slipping from the constellation of Pisces into Aries, reducing in brightness and apparent size as it goes. By the end of the month Mars shines at mag. +0.4 and presents a telescopic disc which appears 7.9 arcseconds across. Mars will move slightly further towards the north during January, exceeding Uranus's declination on the 11th to become the most northerly planet currently in our sky. At the end of January, against a background of darkening twilight, mag. +0.4 Mars is 54° up when due south at 18:05 UT. Although smaller than of late, the higher altitude will assist in stabilising our view of this enigmatic planet.



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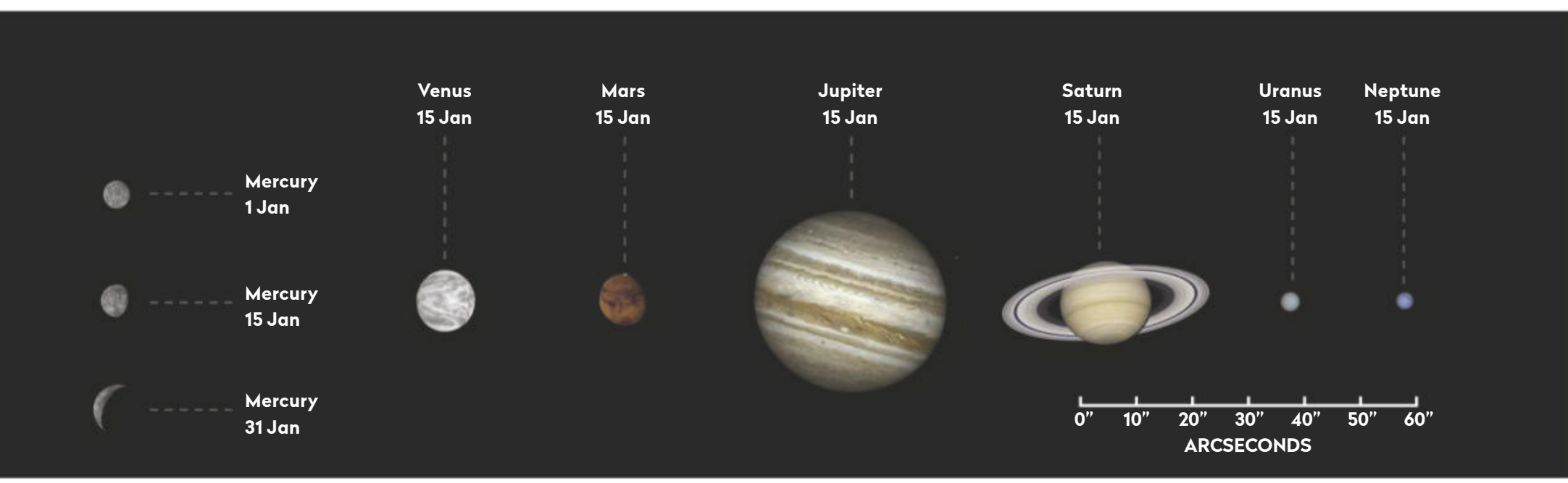
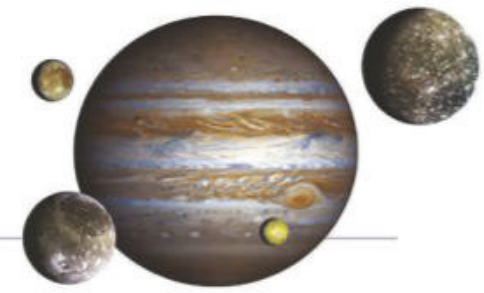
▲ In early January it will still be possible to explore the features of Mars with a telescope

The planets in January

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 24 January, 30 minutes after sunset
Altitude: 9° (low)
Location: Capricornus
Direction: Southwest
Too close to the Sun in the evening sky, Mercury is difficult to see at January's start. After the 7th, it's visible 30 minutes after sunset close to Jupiter and Saturn. Greatest eastern elongation occurs on the 24th, as mag. –0.5 Mercury sets 100 minutes after the Sun. By the 31st, although remaining above the horizon for 90 minutes after sunset, it will be mag. +1.1.

Venus

Best time to see: 1 January, 30 minutes before sunrise
Altitude: 6° (low)
Location: Ophiuchus
Direction: Southeast
Venus is a morning planet rising 1.5 hours before the Sun on the 1st, 55 minutes before on the 15th and 26 minutes before on the 31st. A 4%-lit waning crescent Moon lies 6° west of mag. –3.9 Venus on the 11th.

Jupiter

Best time to see: 10 January, 30 minutes after sunset
Altitude: 5° (low)
Location: Capricornus
Direction: Southwest
Jupiter and Saturn remain close; they begin the month near the Sun, but are then lost in solar glare. Both are visible low above the southwest horizon 30 minutes after sunset at January's start. As Jupiter and Saturn slip toward the Sun, Mercury joins them. On the 9th, mag. –0.8 Mercury appears 3.2° from Jupiter, while on the 10th, Mercury forms an equilateral triangle with Jupiter and Saturn. On the 11th, Mercury forms a right-angled triangle with Jupiter and Saturn, 1.4° from Jupiter. Solar conjunction for Jupiter occurs on the 28th.

Saturn

Best time to see: 10 January, 30 minutes after sunset
Altitude: 3° (very low)
Location: Capricornus
Direction: Southwest
Saturn is close to Jupiter at the month's start, appearing 1.3° away on the 1st. As January progresses, this apparent separation increases. Mercury joins the pair between the 8–13 January, but Saturn is the fainter of the three. On the 24th, Saturn is in conjunction with the Sun.

Uranus

Best time to see: 1 January, 19:40 UT
Altitude: 50°
Location: Aries
Direction: South
Uranus is a mag. +5.7 evening planet in Aries. On the 1st, Mars lies 9.2° to its west-southwest. The planets appear to converge so that by the 19th, they are 1.7° apart. A 58%-lit waxing gibbous Moon joins the scene on the evening of the 21st.

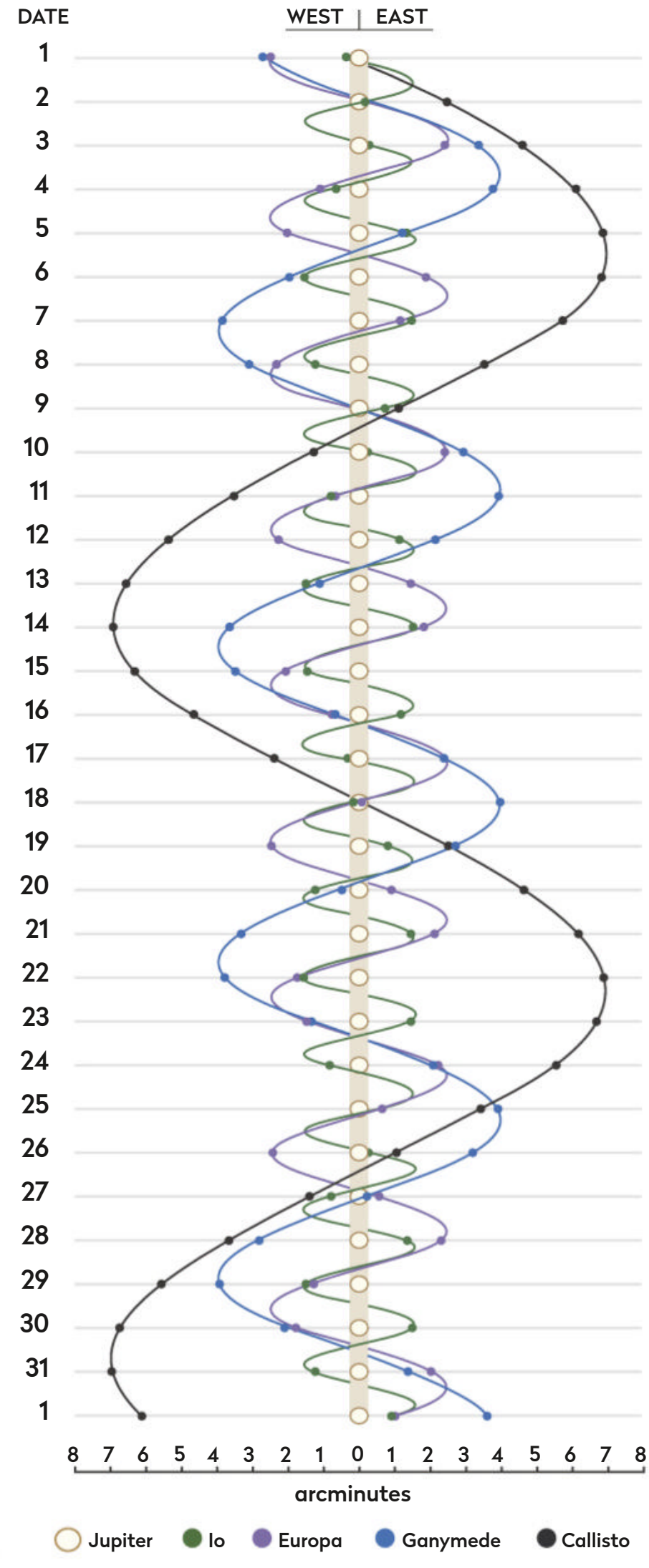
Neptune

Best time to see: 1 January, 18:15 UT
Altitude: 29°
Location: Aquarius
Direction: South-southwest
At the start of 2021 we find Neptune compromised because of its position within Aquarius, unable to be seen at its highest point in the sky under truly dark conditions. The planet appears 27° above the west-southwest horizon when darkness falls on the 1st. As we head toward the month's end, we find that it can only achieve an altitude of 13° above the west-southwest horizon at true darkness.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: JANUARY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – JANUARY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 January at 00:00 UT
15 January at 23:00 UT
31 January at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in January*

Date	Sunrise	Sunset
1 Jan 2021	08:26 UT	16:02 UT
11 Jan 2021	08:21 UT	16:15 UT
21 Jan 2021	08:11 UT	16:32 UT
31 Jan 2021	07:56 UT	16:51 UT

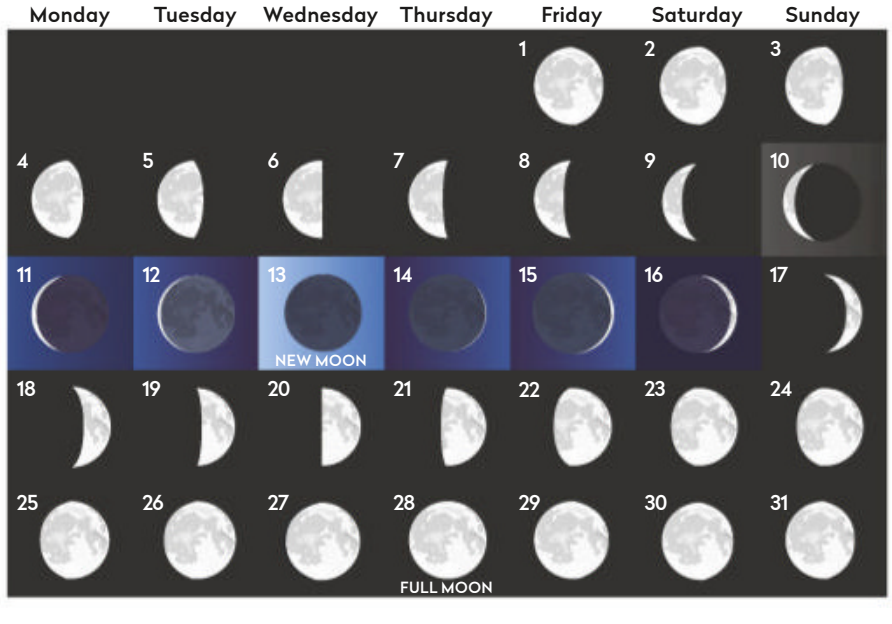
Moonrise in January*

Moonrise times

1 Jan 2021, 18:26 UT	17 Jan 2021, 10:41 UT
5 Jan 2021, 23:53 UT	21 Jan 2021, 11:33 UT
9 Jan 2021, 04:10 UT	25 Jan 2021, 13:09 UT
13 Jan 2021, 09:00 UT	29 Jan 2021, 17:29 UT

*Times correct for the centre of the UK

Lunar phases in January



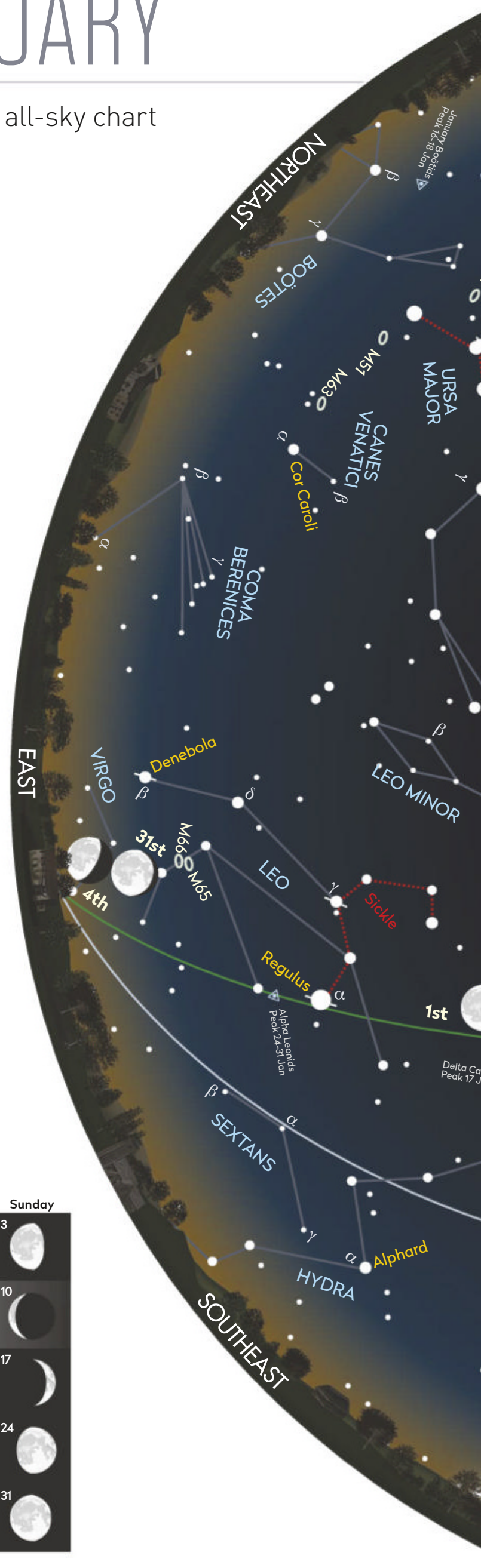


CHART: PETE LAWRENCE

MORE **ONLINE**

Paul and Pete's night-sky highlights

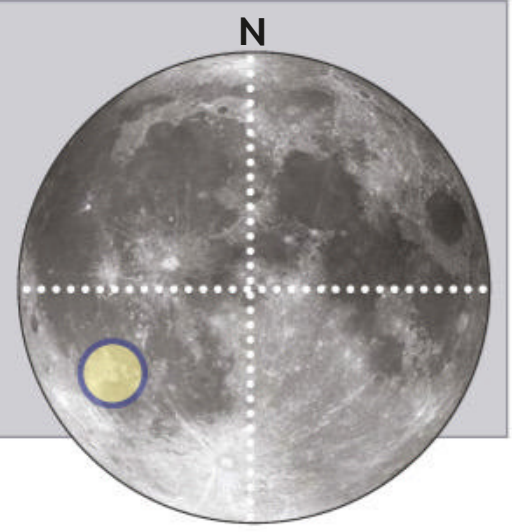
Southern Hemisphere sky guide

MOONWATCH

January's top lunar feature to observe

Gassendi

Type: Crater
Size: 110km
Longitude/Latitude: 40.0° W, 17.6° N
Age: Older than 3.85 billion years
Best time to see: Three days after first quarter (24–25 January) and two days after last quarter (8–9 January)
Minimum equipment: 10x binoculars



Gassendi is a significant feature located on the very northern tip of the 380km-diameter Mare Humorum. When the lighting is oblique, this crater reveals a wealth of detail suitable for small and large telescopes alike.

On first appearance using a low power eyepiece, Gassendi appears like a ring surrounding a highly complex inner floor; a classic example of a type of lunar feature described as a walled plain. The crater's northern rim is interrupted by 33km **Gassendi A**, a bowl-shaped crater that was named 'Clarkson' by Percy Wilkins and Patrick Moore, but the name was never officially recognised. Gassendi's rim is fairly well preserved, especially considering its age. There's a small angular depression in the west, the rim reaching a height of 2.7km just to the north of this region.

The southern edge dips low towards the surface of **Mare Humorum**, on average being elevated by only 150m above the mare's surface. In contrast, the rim section to the north of Gassendi rises to an average height around 600m above Mare Humorum.

A complex set of mountain peaks sits in the centre of Gassendi, rising to a maximum height of 1.37km above the average floor level. The lumps and bumps which comprise the mountain complex appear irregular in distribution, the largest cluster to the south, with a small breakaway group to the northwest. Gassendi's depth is tricky to derive as the crater appears tilted. A measurement relative to the Moon's average radius gives it a value of 2.5km.

Gassendi's floor is covered in a series of fine rilles (narrow channels). These are most noticeable to the southeast, one of the largest running east-west along the northern edge of the flat lava region which coats the southern one-sixth of Gassendi's floor. The rilles are highly detailed when the Sun sits low in Gassendi's sky. A 200mm or larger instrument is recommended to see them, with good steady seeing being highly desirable too. When sunlight obliquely illuminates Gassendi, inner rim terraces also become abundantly obvious.

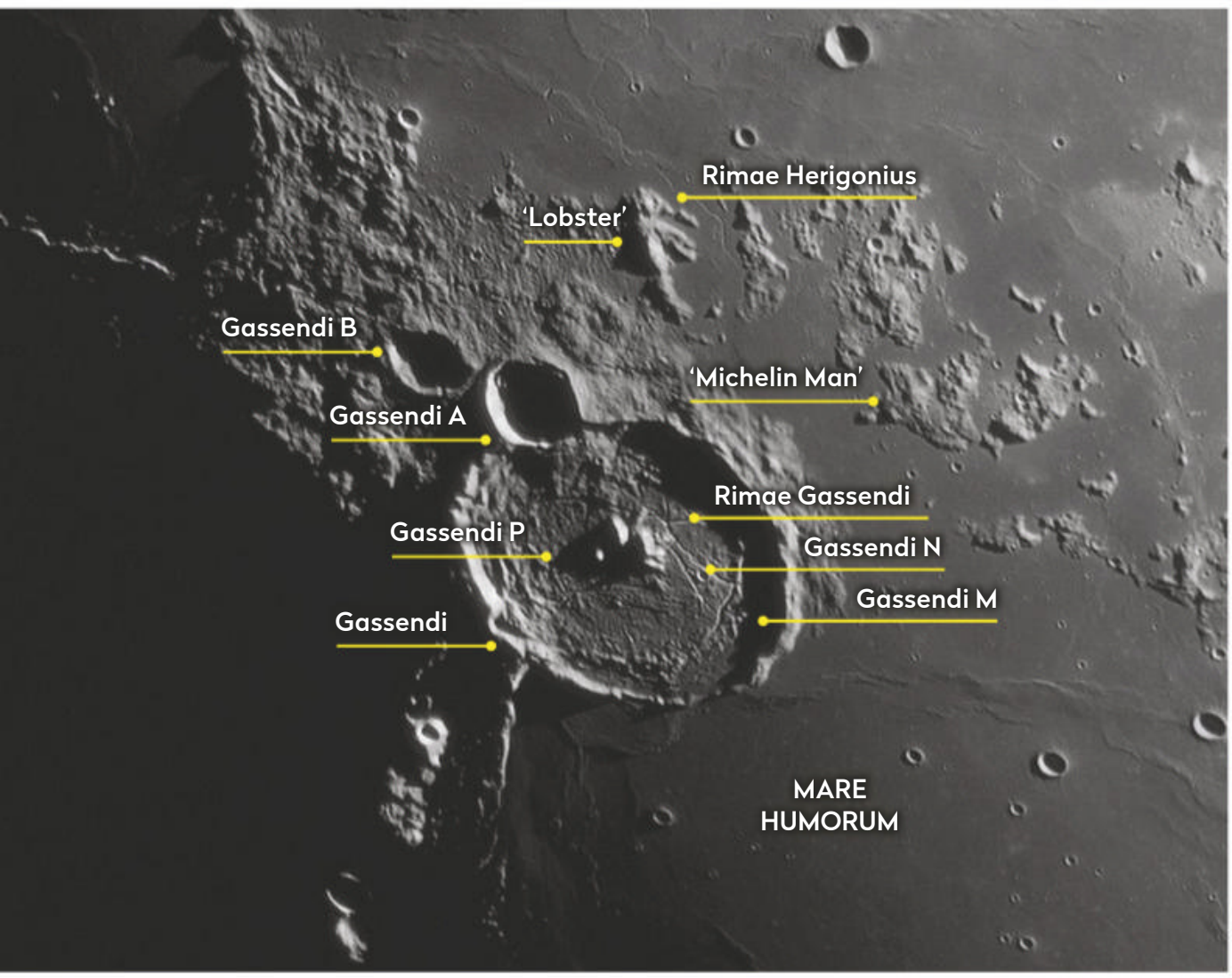
On first appearance Gassendi appears like a ring surrounding a complex inner floor

A couple of interesting elevated features lie to the northeast and east of Gassendi. Located 115km from the centre of the crater to the northeast is a series of connected hills which has been nicknamed the '**Lobster**' or 'Trilobite' due to its shape. Slightly further to the east is a narrow series of cracks, 1km wide, known as **Rimae Herigonius**.

Now look 115km east of Gassendi's central mountain to locate another patch of low hills which appear lighter against the dark surface lava. Both the 'Lobster' and this patch stand out best when the lighting is oblique, this feature being known as the '**Michelin Man**' due to its resemblance to the character of the same name.

If you fancy giving your telescope's optics a workout, look inside Gassendi's rim to locate some of the craterlets it contains. The largest is 3km **Gassendi N**, which should be possible with a 200mm scope. Slightly smaller, **Gassendi M** sits 71km further south, again a viable target for a 200mm instrument. Finally, you'll need at least 300mm of aperture for 2km crater **Gassendi P**, positioned west of the detached northwest part of the central mountain complex.

PETE LAWRENCE X



▼ **Illumination from sunlight reveals inner terraces on the crater Gassendi**

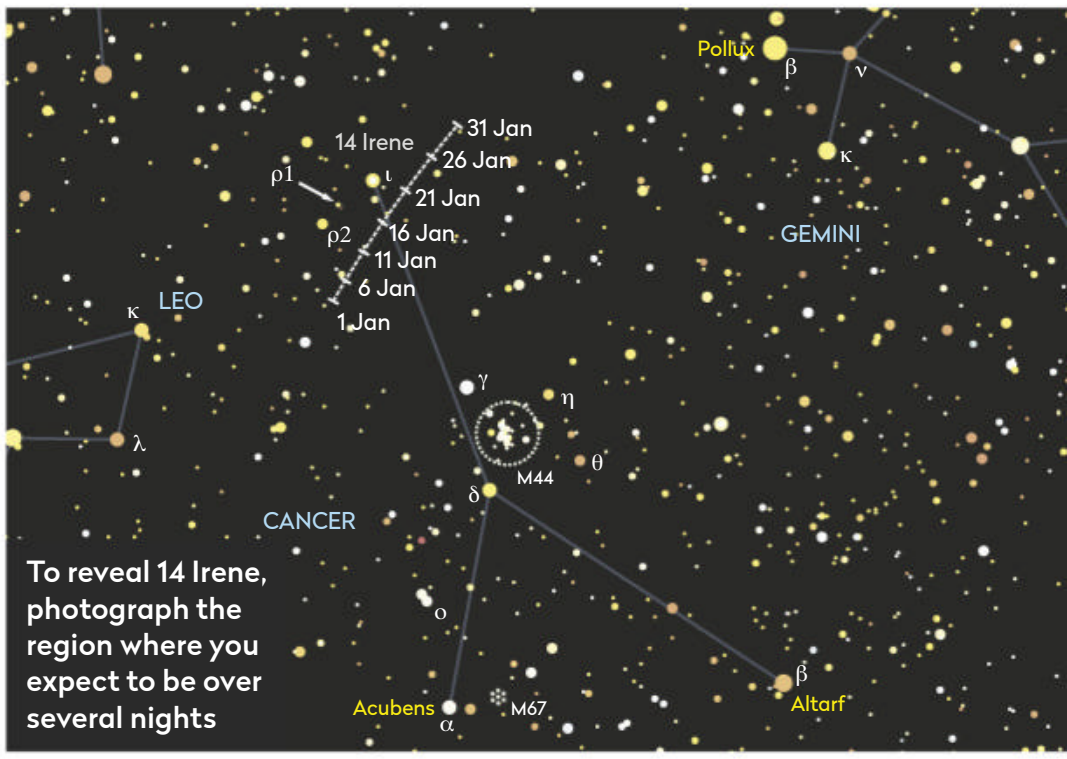
COMETS AND ASTEROIDS

View asteroid 14 Irene as it reaches opposition in the constellation of Auriga

Asteroid 14 Irene reaches opposition in January as it tracks across the northern part of the constellation of Cancer, passing just to the south of mag. +4.0 Iota (ι) Cancri. At 00:00 UT on 1 January, Irene is located 1.5° northwest of mag. +5.4 Nu (ν) Cancri. From here it tracks northwest, passing 1.5° south of Rho[1] (ρ[1]) Cancri and Rho[2] (ρ[2]) Cancri between 7-12 January. These stars are of mag. +6.0 and +5.2 respectively. (As an aside, Rho[1], or 55 Cancri, is a fascinating star located 41 lightyears from Earth and known to have at least five exoplanets in orbit around it.)

Irene passes just over a degree south of Iota Cancri on 16/17 January, ending the month 3.5° west and a fraction north of this star. Its brightness increases slowly over the month, from mag. +9.9 on the 1st up to +9.3 on the 23rd, dipping slightly to +9.4 by the month's close. Opposition occurs on the 24th, when Irene lies 2.316 AU from the Sun and 1.340 AU from Earth.

Irene is a large body orbiting within the main asteroid belt of our Solar System. It has tri-ellipsoidal dimensions of 167km x 153km x 139km and is a dark siliceous, or S-type asteroid, with an albedo – a measure of a body's reflectivity – of 0.16. Irene takes 4.16 years to orbit the Sun and rotates on its axis once every 15.1 hours. It's orbital distance from the Sun varies from 3.02 AU at aphelion to 2.15 AU at perihelion. From Earth, its apparent magnitude can vary from a favourable +8.9 to +12.3. This month's +9.3 opposition magnitude presents an excellent opportunity to spot it; binoculars will show it, but a small scope will give a better view.



To reveal 14 Irene, photograph the region where you expect to be over several nights

STAR OF THE MONTH

Spot Capella, a quadruple star system

Capella (Alpha (α) Aurigae) is Auriga's brightest star and the sixth brightest in the night sky. Its declination of 46° means it's circumpolar from the UK, dipping towards the northern horizon late in the evening in summer, but riding high during late autumn and early winter.

This is the opposite situation to the bright star Vega (Alpha (α) Lyrae), an equally bright star of summer. If you extend a line from Capella through Polaris for the same distance again, it almost takes you to Vega. This means both bright stars act like a giant seasonal sky clock. In many ways Vega and Capella are rivals, the former, at mag. +0.03, being a bit brighter than Capella at mag. +0.08. In the northern half of the night sky, only Arcturus (Alpha (α) Boötis) is brighter.

Capella appears to have a yellowish colour and turns out to be a quadruple system organised as two binary pairs in mutual orbit around each other. The main pair are two giant stars, Capella Aa and Capella Ab. The former is an orange giant of spectral type K0III, while the latter is a yellow giant of type G1III. Two red giants, Capella H and Capella L, form a second pair with spectral types of M2.5 and M4 respectively.

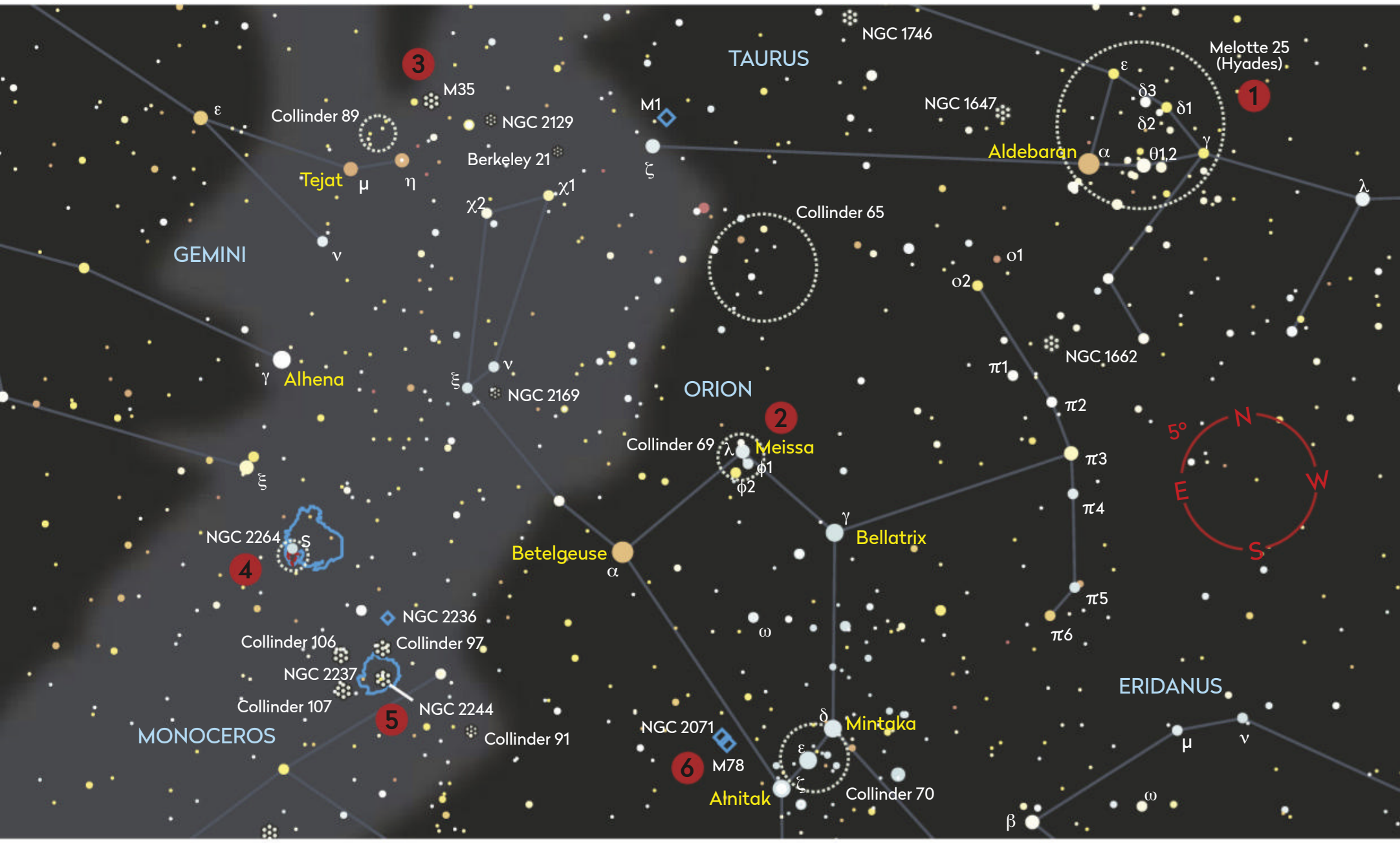
Capella Aa and Capella Ab form a tight pair, being separated by 0.74 AU, in a 104-day circular orbit. Through amateur scopes they are too tight to split, but Capella H and Capella L, sitting 12 arcminutes to the southeast of Capella, can be split with high magnification. They appear separated by 3 arcseconds, the brighter component Capella H at mag. +10.2 and Capella L at mag. +13.7.

Capella is the brightest star in the constellation of Auriga

BINOCULAR TOUR

With Steve Tonkin

The easy to spot Hyades and tricky M78 are among January's wide-field targets



1. The Hyades

10x 50 The Hyades cluster is next to Aldebaran (Alpha (α) Tauri), the ruddy 'Eye of the Bull', which is a foreground star. This huge cluster is only 153 lightyears away, making it the nearest open cluster to us, and you should easily see 30 or more stars. The Hyades were the daughters of Atlas, whose tears of grief for their slain brother, Hyas, are the April rain showers that are associated with their heliacal setting. ☐ **SEEN IT**

2. The Meissa Cluster

10x 50 Orion's head looks distinctly fuzzy to the naked eye and, when you look at it through binoculars, you immediately see why: it is a small cluster of stars dominated by the brilliant white Meissa (Lambda (λ) Orionis), also called Heka, 'the white spot'. The other two bright stars in the field of view are the sapphire blue Phi^1 (ϕ^1) Orionis, and deep yellow Phi^2 (ϕ^2) Orionis, which is probably not part of the cluster. ☐ **SEEN IT**

3. The Queen of Clusters, M35

10x 50 Find Tejat (Mu (μ) Geminorum), put it at the southeast edge of your field of view and look for a large misty patch near the opposite side. Under suburban skies you should be able to resolve at least 10 stars with 10x50 binoculars in this 'Queen of Clusters'. If you have dark skies, use averted vision to try to glimpse a smaller (5 arcminute diameter) cluster, NGC 2158, 0.5° to the southwest. ☐ **SEEN IT**

4. The Christmas Tree Cluster

10x 50 About 6.5° south of Alhena (Gamma (γ) Geminorum) you will find, surrounding the slightly variable (mag. +4.6 to +4.7) blue star S Monocerotis, the seasonally appropriate Christmas Tree Cluster, NGC 2264. S Monocerotis is the trunk of the narrow wedge of stars that forms the inverted tree. Despite being in the Milky Way, there are few faint stars in the vicinity here, due to a large amount of interstellar dust in the region. ☐ **SEEN IT**

5. NGC 2244

10x 50 Next, head 5.5° south-southwest from NGC 2264 to a narrow rectangular group of stars, about 25 arcminutes long, that looks more like a denser accumulation in the Milky Way than an actual cluster – there is no tell-tale background glow from fainter stars. With good skies, you may detect the glow of the Rosette Nebula, from which these stars formed. ☐ **SEEN IT**

6. M78

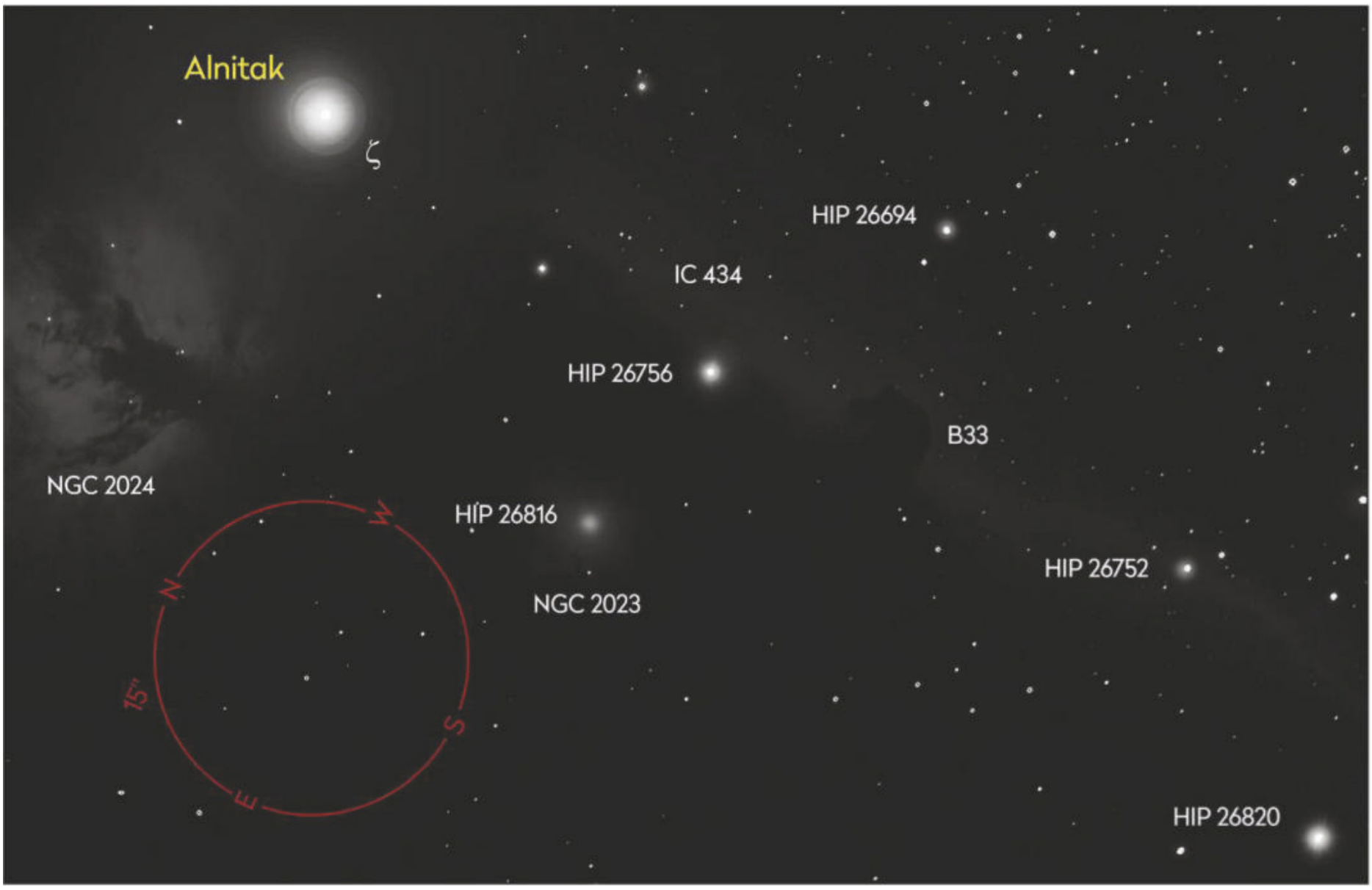
15x 70 You will need mounted binoculars, a transparent sky and averted vision for M78; Alnitak (Zeta (ζ) Orionis) is just outside the south-southwest of the field of view and a small misty glow should appear near the centre. You will notice that it's brighter at the top than at the bottom, giving the appearance of a comet. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Can you see the Horsehead Nebula, an infamously tricky dark nebula?



The Horsehead Nebula is one of the most iconic deep-sky objects there is. It's formed by a finger of dark nebulosity projecting in front of bright emission nebula IC 434. The finger resembles the silhouette of a horse's head, similar to the side-on profile of a classic knight chess piece. The darker nebulosity which forms the nebula is known as B33, the 33rd entry in the Barnard Catalogue of dark nebulae. Your challenge this month is to try and see the Horsehead Nebula visually.

The Horsehead Nebula's image is found everywhere – in books, online and on wall posters. However, despite deep-sky images showing its background curtain as bright, visually the nebula is extremely dim. A 12-inch reflector is probably the minimum you need to see it from typical UK skies, but smaller instruments may return a view of the nebula from darker sky locations. The use of a hydrogen-beta (H-beta) filter is also highly recommended.

To get started, first look for NGC 2024, the Flame Nebula, located east of Alnitak (Zeta (ζ) Orionis). It's so close to Alnitak that the star's glare makes it tricky to see. If you can see NGC 2024, that's the first hurdle passed; if you can't, then it's unlikely that you're going to be able to see the Horsehead.

The Horsehead Nebula is one of the most iconic deep-sky objects there is

The two key stars needed to locate the Horsehead are mag. +7.5 HIP 26756 and HIP 26820, the latter a tight pair of mag. +6.4 and +7.6 stars separated by 0.7 arcseconds. The brighter edge of the curtain of nebulosity IC 434, forming the backdrop for B33, runs between HIP 26756 and HIP 26820.

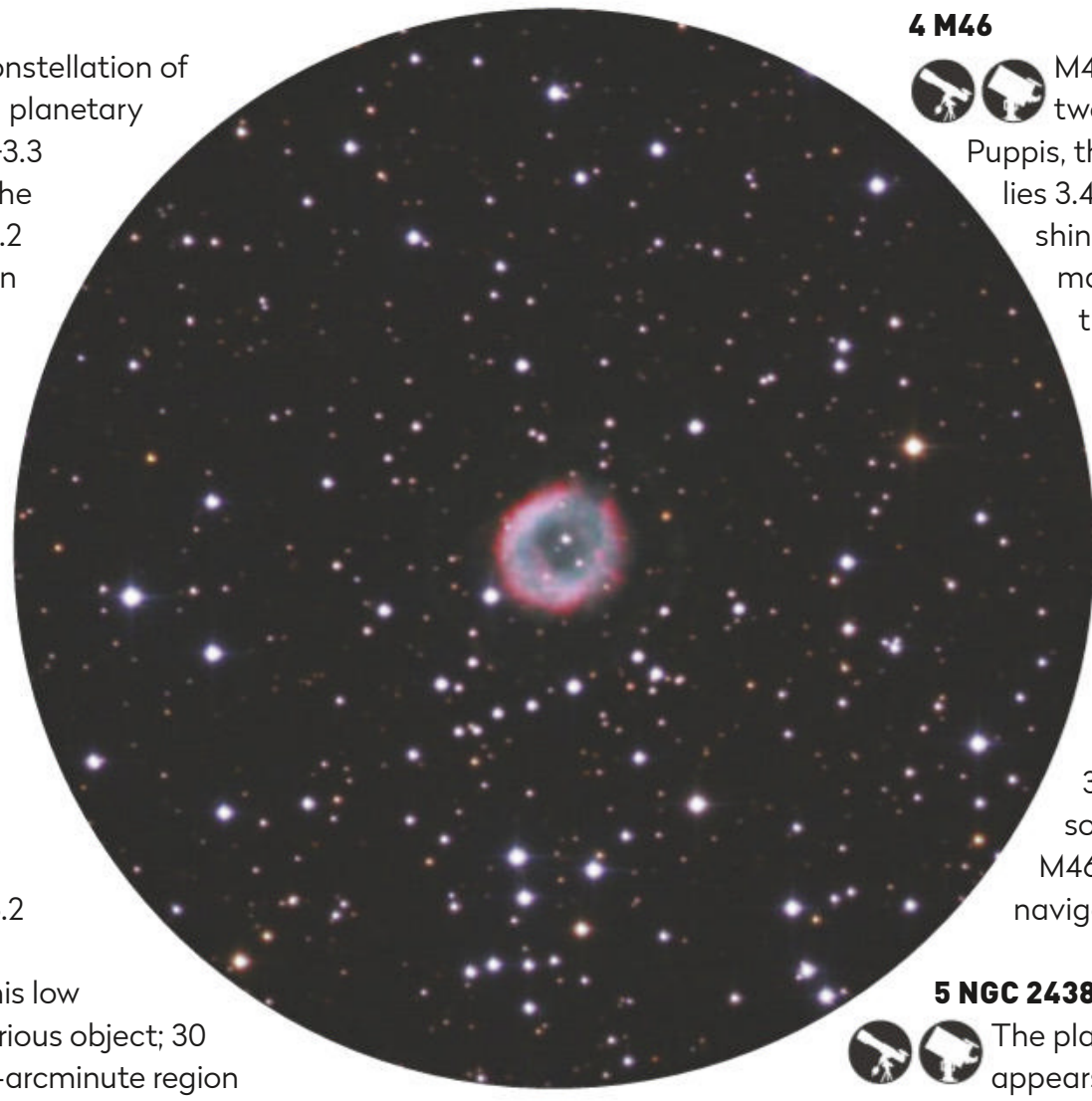
Using our chart, locate mag. +7.8 HIP 26816 just to the east of HIP 26756. A reflection nebula, NGC 2023, surrounds HIP 26816. Without the filter, look to see whether you can get a hint of it. If so, you're all set for the Horsehead attempt. If not, you're unlikely to succeed with the main challenge.

You'll need dark skies and your eyes will need to be properly dark-adapted, meaning no light at all for at least 20 minutes. If you place a black cloth over your head that may also help. Just take your time and look for the faintest hint of nebulosity between HIP 26756 and HIP 26820. This can be very hard, so give your eyes time to get accustomed to the view. Averted vision with the aid of an H-beta filter is the best way forward here. If you can see it, the Horsehead appears as a tiny dark notch approximately one-quarter the way from HIP 26756 towards HIP 26820.

Make no mistake, this is a very tricky challenge. Light pollution will almost certainly render the Horsehead Nebula invisible. However, if you do manage to see and record it, please let us know.

DEEP-SKY TOUR

We begin explore the celestial treasures in the constellation of Puppis, the Poop Deck



▲ **Planetary nebula NGC 2438 is around 1,370 lightyears distant**

CHART BY PETE RUDOLF DOBESBERGER/CCDGUIDE.COM,

1 NGC 2452

We start low in the constellation of Puppis; NGC 2452 is a planetary nebula 2.4˚ south of mag. +3.3 Asmidiske (Xi (ξ) Puppis). The nebula is listed at mag. +12.2 and although it can be seen through smaller scopes, requires at least 250mm of aperture to start to see properly as a faint, mostly featureless oval. A 300mm scope shows brighter patches to the north and south of the main nebula. NGC 2452 appears quite large, with an apparent size of 30x20 arcseconds. ☐ **SEEN IT**

2 M93

M93 is a mag. +6.2 open cluster, 1.5˚ northwest of Asmidiske. This low declination Messier is a glorious object; 30 members packed into a 10-arcminute region through a 150mm instrument. Larger instruments reveal an object expanded to an apparent size just over 20 arcminutes; M93 has over 100 members.

Located at a distance of 3,600 lightyears, the cluster mostly consists of blue giant stars with a small number of red giants. Visually the cluster appears wedge-shaped, two brighter stars sit close to the tip of the southwest pointing wedge. ☐ **SEEN IT**

3 NGC 2440

NGC 2440 is listed at mag. +9.4 and is bright enough for a small scope. Sitting in a region of sky devoid of bright stars, one way to locate it is to extend the line from Sirius through mag. +4.3 Iota (ι) Canis Majoris for 3.8 times that distance again. Alternatively, head 6.3˚ north of Asmidiske, then drift 1.6˚ west. A 250mm scope shows an elongated 30x20 arcseconds object which loses its stellar appearance around 100x magnification; the central region appears 15 arcseconds across and circular. A 300mm scope at 400x magnification reveals the central area consists of two bright lobes arranged at right angles to the long axis of the now 40x20 arcsecond glow of the main nebula. ☐ **SEEN IT**

4 M46

M46 is the easternmost of two close clusters in northern Puppis, the other being M47. M46 lies 3.4˚ north of NGC 2440, and shines with an integrated magnitude of +6.1; theoretically visible to the naked eye from a good, dark site. This is a rich open cluster roughly 20 arcminutes across. Over 70 stars are visible through a 150mm scope, spread uniformly across the area with no real central condensation.

A mag. +5.0 red star, HIP 37379, sits half-a-degree southwest of the centre of M46, and this can be used to navigate to target 5. ☐ **SEEN IT**

5 NGC 2438

The planetary nebula NGC 2438 appears embedded in M46. If you can visualise where the approximate centre of M46 is visually, imagine the line between the mag. +5.0 red star HIP 37379 mentioned earlier, and NGC 2438's centre. Keep going for around 5 arcminutes to reach the nebula. The distance between HIP 37379 and M46's centre is 34 arcminutes.

NGC 2438 doesn't share the same radial velocity as M46 and is thought to be unrelated to the cluster. Its appearance within M46 is simply a line-of-sight effect. In reality, NGC 2438 is a foreground object around 1,370 lightyears away, a little over a quarter of M46's 4,920-lightyear distance. It shines at mag. +10.8 and has an apparent size of 1.1 arcminutes. ☐ **SEEN IT**

6 M47

Open cluster M47 is 1.3˚ west and a fraction north of M46. At mag. +4.4, it's an easy naked-eye object. M47 exhibits a good distribution of star brightness. The brightest star lies on the western side and is a double, with components of magnitudes +5.7 and +9.7 separated by 20 arcseconds.

A 150mm instrument shows around 50 stars within a region 30 arcminutes across. Increased aperture ups this number, a 250mm scope revealing about 80 stars.

This lovely Messier was once considered lost. Although cluster NGC 2422 was known, Messier's coordinate offset from seventh magnitude 2 Puppis, 2.2˚ to the east, pointed to nothing. It took Canadian astronomer TF Morris to realise that the signs on Messier's offsets were wrong. Switch signs and it's clear that NGC 2422 is actually M47. ☐ **SEEN IT**

This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

MONOCEROS

PUPPIS

CANIS MAJOR

α

-10°

NGC 2353

NGC 2343

07h00m

θ

NGC 2396

Melotte 71

Hafner 8

Hafner 6

NGC 2345

NGC 2506

08h00m

-10°

NGC 2374

NGC 2423

5

NGC 2539

NGC 2438

6

M47

NGC 2414

NGC 2360

Muliphein

γ

α

Sirius

M46

HIP 37379

4

ι

Bochum 5

Bochum 4

ν3

ν1

ν2

3

NGC 2440

N

5°

2°

W

E

S

NGC 2509

Ruprecht 46

NGC 2421

NGC 2384

NGC 2383

NGC 2367

ξ2

-20°

o2

o1

Collinder 121

2

11

M93

Trumpler 7

NGC 2362

NGC 2354

NGC 2482

Asmidiske

ξ

ρ

Ruprecht 18

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Wesen

07h00m

PGC 2801154

NGC 2613

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Ruprecht 32

Trumpler 9

Hafner 19

Hafner 19

NGC 2467

NGC 2280

08h00m

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NGC 2453

NGC 2452

1

Adhara

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Aludra

NGC 2483

1

3

NGC 2527

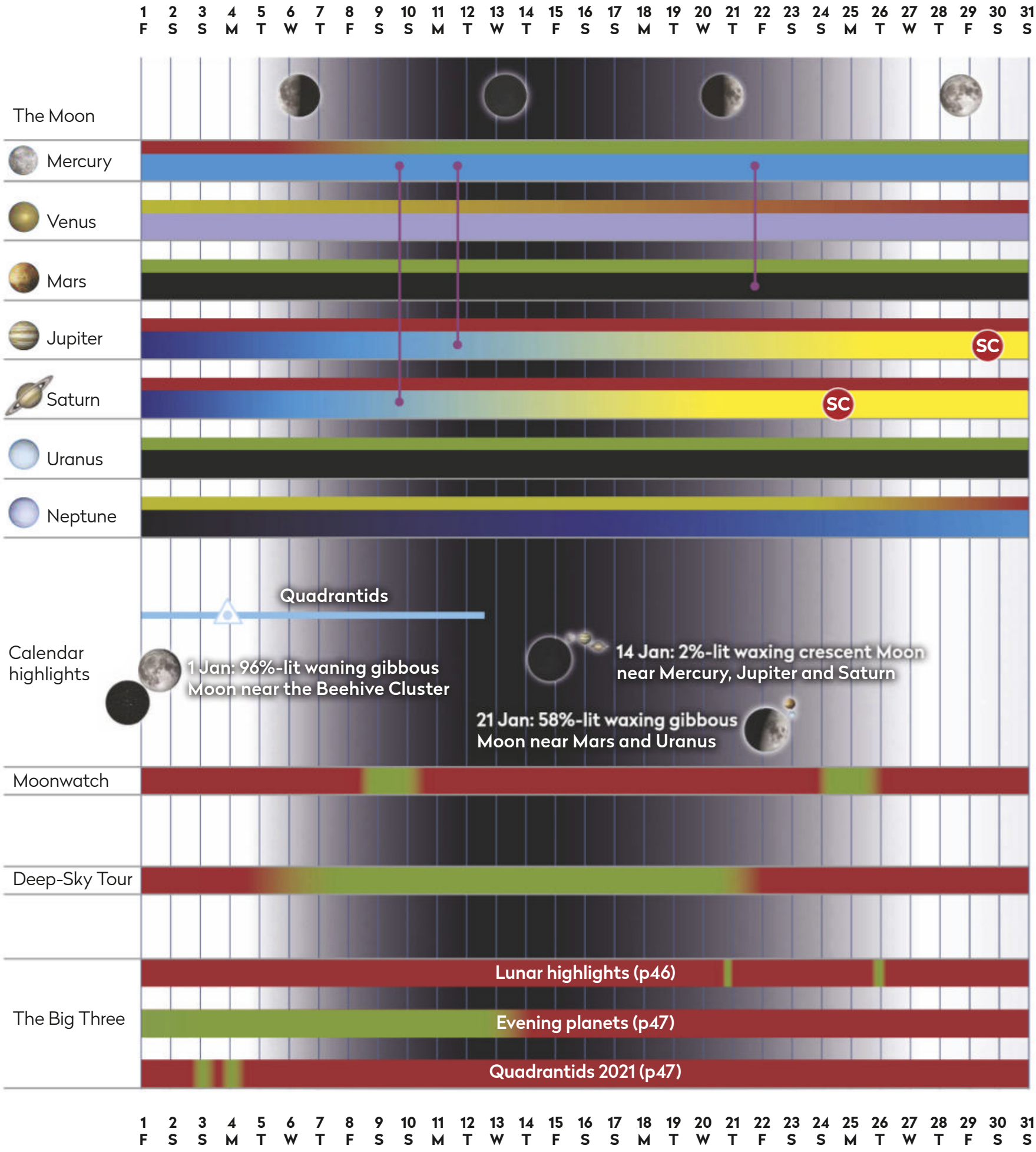
Ruprecht 44

Collinder 132

-30°

AT A GLANCE

How the Sky Guide events will appear in January



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

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BBC Sky at Night MAGAZINE

APOLLO 14

With support for the Apollo programme waning, NASA stepped up its scientific endeavours for Apollo 14, as **Ezzy Pearson** reports

When Apollo 14 launched on 31 January 1971, it carried the weight of the entire Apollo programme. The Apollo 13 disaster had recaptured the public's dwindling interest, but for all the wrong reasons. Policymakers already questioning Apollo's high cost, having cancelled Apollo 18 and 19 in September 1970, now wondered at its safety. If the remaining missions were to fly, then Apollo 14 had to be a success.

It was a heavy responsibility, and one that rested on the most inexperienced crew of the whole Apollo programme. The Commander, Alan Shepard, was one of NASA's most famous astronauts, having been the first American to reach space back in 1961. However, he'd spent the best part of the intervening decade grounded due to an ear problem that caused vertigo. Joining him were two rookie astronauts – Command Module Pilot Stuart Roosa and Lunar Module Pilot Edgar Mitchell – neither of whom had flown in space.

Despite having a sum total of 15-minutes spaceflight experience, the mission had the most intensive scientific programme yet. Apollo 13 had been heading towards an important landing site – Fra Mauro, a formation created by the ejecta of the collision which created Mare Imbrium. This impact would have kicked up rocks from much deeper beneath the surface, which could potentially allow geologists to date the formation of the Moon. With the risk that the Apollo programme could be cancelled at any moment, Apollo 14 was re-planned to visit this scientifically vital area.

The importance of the site, however, was somewhat lost on the two moonwalkers, Shepard

MISSION BRIEF

Launch date: 31 January 1971

Launch location: Launch Complex 39A

Landing location: Fra Mauro

Time on surface: 1 day, 9 hours, 30 minutes

Duration: 9 days, 1 minute

Return date: 9 February 1971

Main goals: investigate the Fra Mauro region; orbital science and high-resolution photography of future candidate landing sites; Lunar field geology investigations.

Achievements: furthest distance travelled in an EVA (almost 1km) in the Apollo programme so far; first science programme from lunar orbit; first golf drive on the Moon

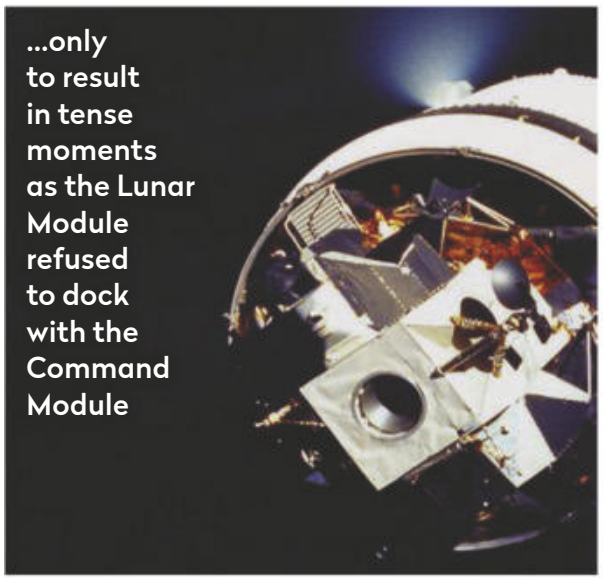
Lunar module name: Antares

Command module name: Kitty Hawk

NASA X 13

Shepard looks up at the unfavourable weather conditions on launch day...


... luckily the weather cleared leading to a successful lift off


...only to result in tense moments as the Lunar Module refused to dock with the Command Module

"Al is on the surface. And it's been a long way, but we're here." – Alan Shepard on first stepping onto the surface.


Raising the flag: Alan Shepard poses next to the US flag on 5 February 1971

and Mitchell. Neither were geologists and though they had had a crash course in identifying rocks, Shepard never developed an interest in the science. Whether his celebrity ego or the pressure of commanding the mission after a decade on the ground was to blame, his lack of enthusiasm rubbed off on Mitchell.

Launch approaches

When launch day came around, NASA was hoping for an easy start to the mission, only for bad weather to cause a delay. If the skies didn't clear within the four-hour launch window, the mission would be scrubbed until March, leaving the rocket open to the elements on the launch pad for a month. Fortunately, after 40 minutes the weather improved, and the crew of Apollo 14 began their journey to the Moon.

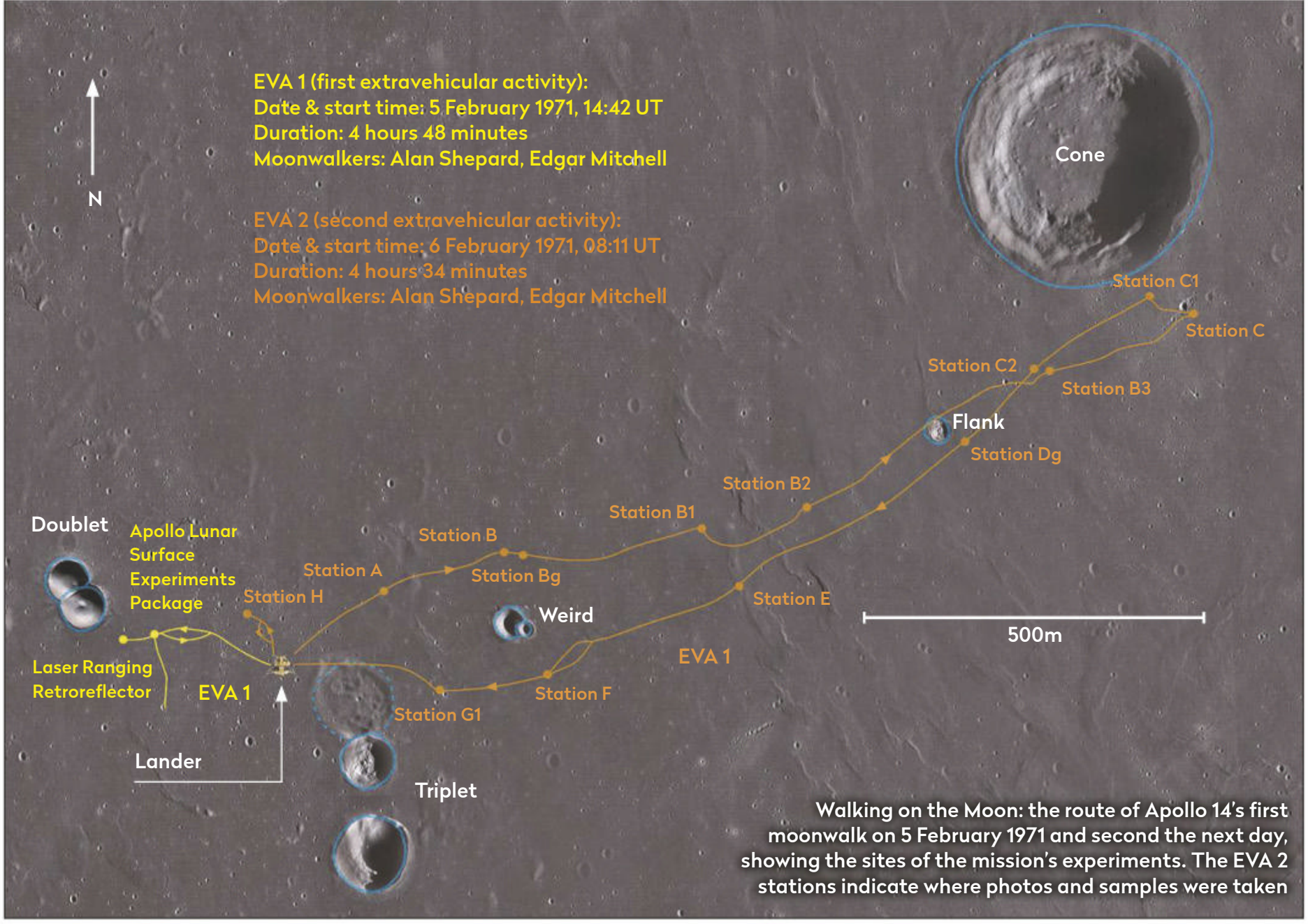
It only took a few hours for things to go wrong again. When Roosa attempted to extract the Lunar Module, Antares, and dock it with the Command Module, Kitty Hawk, the two refused to latch together. If he couldn't get them connected, the lander was useless and there'd be no landing. After five failed attempts, Roosa took a last-ditch brute force approach, finally making the connection. ▸

Meet the astronauts

Commander: Alan Shepard
At 47, former navy pilot Alan Shepard was the oldest Apollo astronaut. He was the first American in space during his Freedom 7 mission on 5 May 1961. He served as Chief of the Astronaut Office from 1963–1969, before joining the Apollo programme. He left NASA in 1974 to pursue philanthropic ventures. He died on 21 July 1998.

Lunar Module Pilot: Edgar Mitchell
Mitchell was originally a navy pilot, joining NASA in 1966. After leaving in 1972, he continued to pursue his interest in the paranormal, including setting up the Institute for Noetic Sciences to investigate the metaphysical power of the human mind, and made several statements about UFOs before his death on 4 February 2016.

Command Module Pilot: Stuart Roosa
Roosa began his career as a 'smokejumper' – rapid response firefighters who parachute into wildfires – before joining the Air Force. He was selected as an astronaut in 1966, but Apollo 14 was his only spaceflight. He later worked on the Space Shuttle programme until retiring from NASA in 1976. He died on 12 December 1994.



Walking on the Moon: the route of Apollo 14's first moonwalk on 5 February 1971 and second the next day, showing the sites of the mission's experiments. The EVA 2 stations indicate where photos and samples were taken

▸ Thankfully, this coarse manoeuvre didn't damage Antares and the lander touched down successfully on the lunar surface on 5 February. The crew immediately prepared for their first extra vehicular activity (EVA), only to discover a fault in the communications system, requiring another delay. Had they come this far only to fail at the last moment? Fortunately, the problem was quickly fixed and just five and a half hours after landing on the Moon, Shepard and Mitchell were ready to head out.

For their initial sojourn, the astronauts didn't stray far from Antares, instead using the time to offload their equipment and set up experiments around the lander. While many of these were the same suites of seismometers and detectors from previous missions, one novel experiment involved detonating dozens of 'thumper' charges, the vibrations of which were picked up by instruments left on previous landings.

Moon trek

The second EVA the next day, however, was much more demanding. The moonwalkers had to live up to the 'walk' part of their name and trek towards crater Cone around 1km away. It was the longest journey of the programme so far and to help cart their equipment around, the crew used a wagon officially named the Modular Equipment Transporter, but known to the astronauts as the 'rickshaw'.

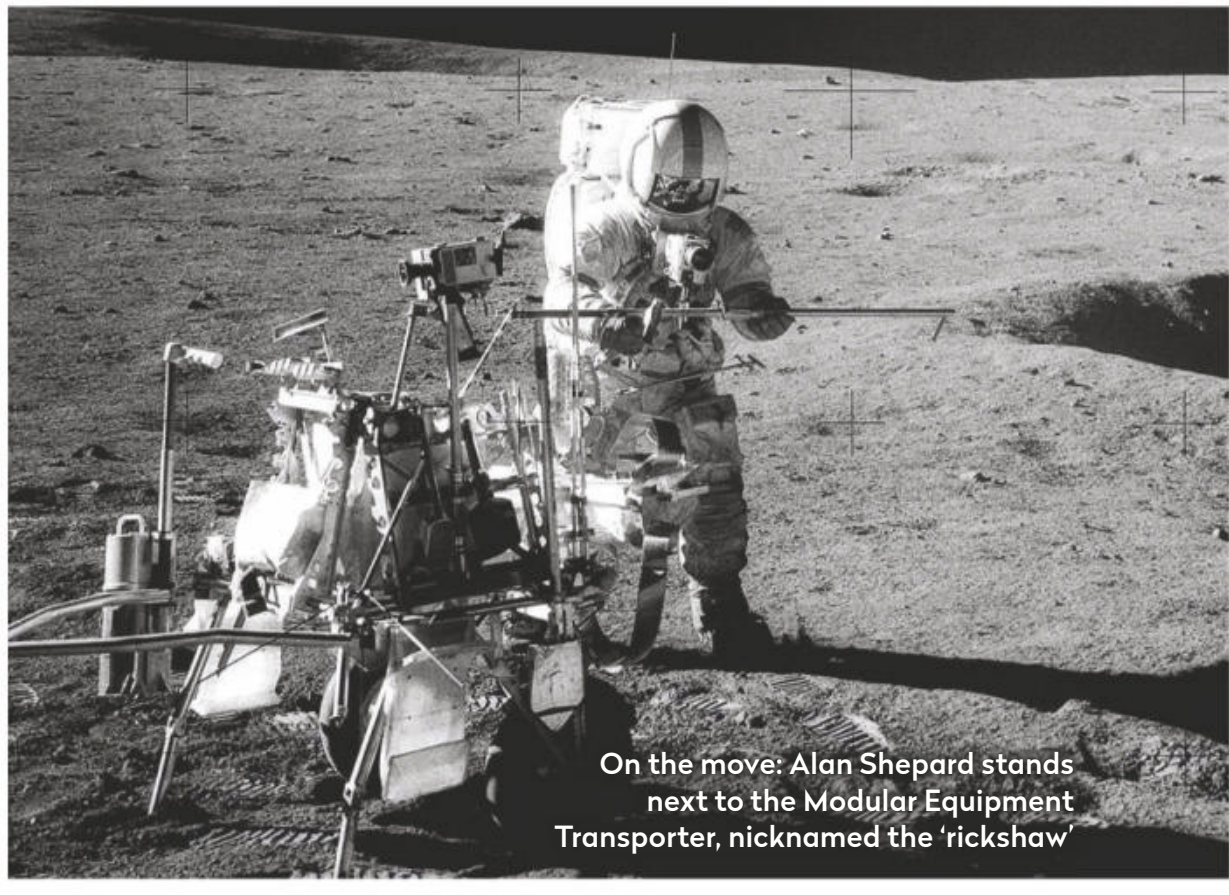
The pair soon found navigating the lunar surface was far harder than either had anticipated. With no atmosphere to diffuse the light, it was difficult to judge distances, while landmarks that were obvious on maps became unrecognisable on the surface.

"You can sure be deceived by slopes here," said Mitchell while on the surface. "The Sun angle is very deceiving."

After two hours, the pair thought they were about to reach the crest of the crater's rim, only to see the field of boulders stretching out before them. The long walk pulling the heavy cart was rapidly exhausting the astronauts and Mission Control was getting worried about their rapid heart rates. The pair were given another 30 minutes to find crater Cone's rim before they were told to stop, take their samples and come back. It would later turn out that the astronauts had stopped just 20m short of the crater's edge.

Meanwhile, in orbit, Roosa was conducting his own scientific study – the first time a Command Module pilot had been called on to do so. He was meant

"Unfortunately, the suit is so stiff, I can't do this with two hands, but I'm going to try a little sand-trap shot here." – Alan Shepard practices his golfing technique


On the move: Alan Shepard stands next to the Modular Equipment Transporter, nicknamed the 'rickshaw'

NASA X 5, EVA MAP ILLUSTRATION BY PAUL WOOTTON

MISSION TIMELINE

31 January 20:15*
Countdown paused with eight minutes left on the clock

31 January 21:03
Apollo 14 launches

31 January 21:03
Engine burn sends the spacecraft on a trajectory towards the Moon

1 February 00:16
First attempt at docking the Lunar Module (LM) and Command Module (CM)

1 February 01:59
Docking finally successful

3 February 08:53
LM pressurised; the Commander and Lunar Module Pilot transfer across

5 February 09:18
The LM lands on the Moon's surface

5 February 14:42
First EVA begins

5 February 15:44
US flag deployed on the surface

6 February 08:11
Second EVA begins. Shepard and Mitchell begin hike to crater Cone

6 February 10:43
Moonwalkers reach Station C1, the closest point to crater Cone

6 February 18:48
The LM launches from the Moon

6 February 20:35
The LM redocks with the CM

9 February 21:05
The CM splashes down on Earth

***All times are UT**

▲ An oblique shot of crater King, one of the few images Roosa took from the Command Module

▲ That's one giant swing for mankind: Shepard takes pot shots with his golf club across the lunar surface

▲ Shepard and Mitchell collected their fair share of rocks, but were unable to get any from crater Cone

▲ The Apollo 14 crew on the *Tonight Show* on 8 March 1971. Mitchell (yellow jacket) would go on to become a fierce advocate for UFO visitations and the paranormal

to image the lunar surface with a special Hycon Lunar Topographic Camera, but the shutter kept sticking, ruining half of the images. Fortunately, he managed to snap a few photographs with the Hasselblad cameras carried by every Apollo crew, including some shots of the future landing site of Apollo 16.

Back on the surface, the moonwalkers returned to the lander, but just before climbing onboard, Shepard pulled out a 6-iron golf club head he'd smuggled on board. He attached it to the handle of his lunar excavation tool and proceeded to take a couple of drives.

"There it goes," said Shepard. "Miles and miles and miles."

This didn't go over at all well with the scientific community. While lining up his swing, Shepard had put down a canister of photographs documenting several of the rock samples they'd collected, and he forgot to pick it up afterwards. Not only had the geology teams missed out on getting the samples from the rim of crater Cone, they now lacked the documentation that would really let them exploit the scientific usefulness of the ones they did have. The feelings of ill-will only grew when Mitchell, upon his return to Earth, publicly announced that he'd conducted an unofficial pseudoscience experiment, attempting to psychically transmit messages back to Earth.

While headlines and history books remembered Apollo 14 for Shepard's golf swing, for many at NASA it was a squandered opportunity. The moonwalkers were meant to bring back the most important moonrocks of the entire programme, reminding people of the importance of Apollo. Instead, they were seen as making a mockery of everything the agency was trying to achieve.

Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

PICKING UP A BARGAIN:

a guide to buying second-hand kit

Using pre-owned equipment is a great way to get into astronomy and stay on budget. **Charlotte Daniels** takes us through the dos and don'ts of buying used gear

There is a thriving market in second-hand astronomy equipment, helped by the fact that astronomers generally tend to take good care of their kit, so that when they choose to sell it on to someone else it's usually in pretty good shape. As well as helping you to save money in what can be an expensive hobby, buying from someone who has actually used an instrument before you has another benefit – they can pass on their wisdom.

It can be daunting for a newcomer to come into the second-hand marketplace for the first time, however, so here we take a look at some of the most practical questions to ask before making a purchase – for example, the types of photos of an item you should ask to request to see – to help make sure you get the best kit with minimum hassle. ▸

Top tips

Before you start looking, here are some important pointers to bear in mind

▸ **Check photos:** Before you make a purchase, always look carefully at any photographs. Be wary of any adverts using catalogue or website photos for a product, or which have no photos. Almost everyone has access to a smartphone camera these days, so never be afraid to ask for more photos if you have any doubts.

▸ **Make sure you have all the parts:** If you're asking for something with multiple parts (such as a star tracker package) ask for pictures of everything being sold, including cables and accessories. Make sure you check this against a list of the equipment you would expect to get if it was being sold new.

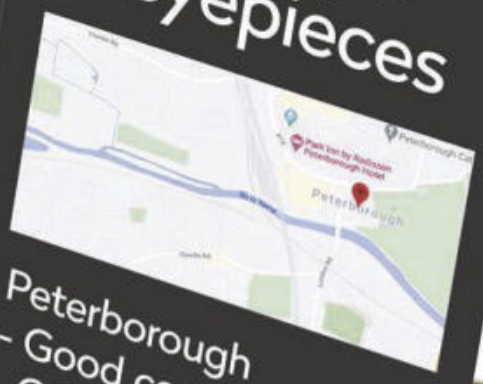
▸ **Ask if there are any repairs or modifications:** It's not unusual for astronomers to modify kit to adapt it to their needs. Some of these modifications can improve the quality of the instrument for a specific purpose, but others might not be so welcome.

▸ **Arrange a safe place to pick up items:** COVID-19 has highlighted a need to get things delivered where possible, but there will be some items that are better to collect in person – when you need to check the equipment or find out how to set it up. If collection is best (and it's safe and legal) ask ahead to see if there's an outdoor area to check things over. Let someone know where you are going and take someone with you if you can.

▸ **Ensure you have an appropriate way to pay:** If arranging collection, agree the method of payment beforehand. Some sellers prefer cash, but others will want PayPal or bank transfer. Have the payment method ready should you wish to accept the item. With bank transfers, the buyer has less protection. If you are using PayPal, ensure the seller uses 'PayPal purchase', rather than 'friends and family', as this option gives more protection.

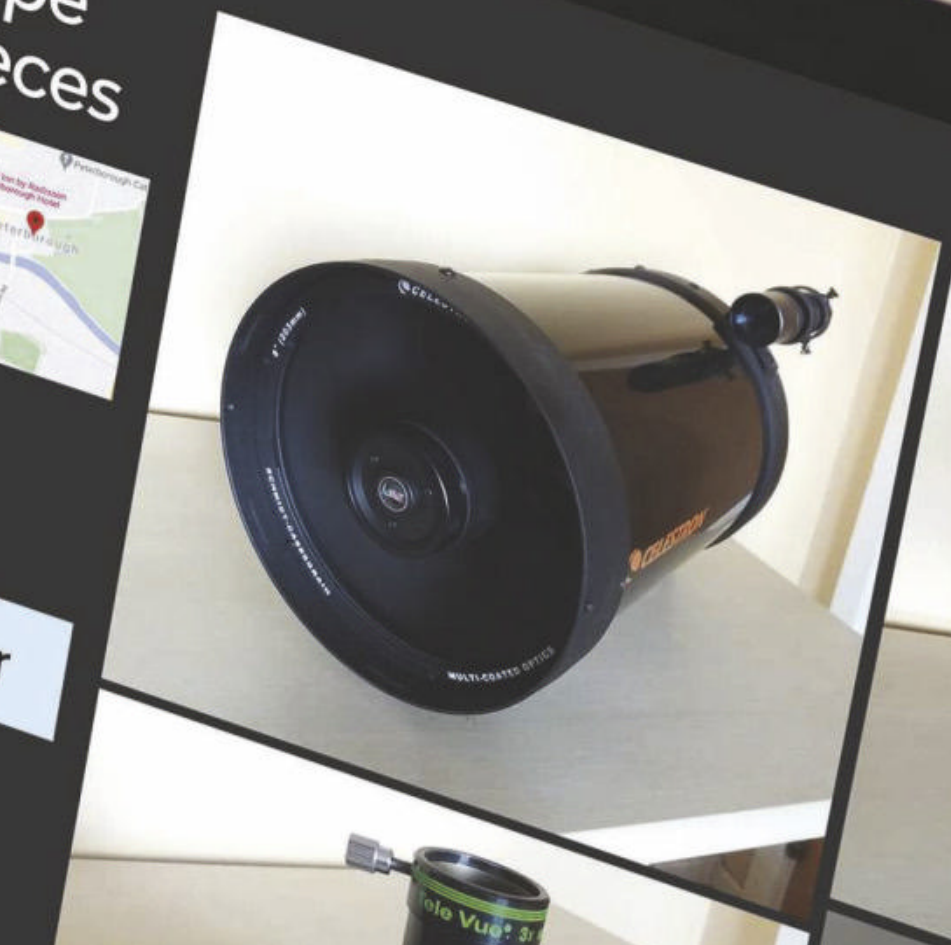
BONGKARNTHANYAKIJ/ISTOCK/GETTY IMAGES, STEVE MARSH X 4, ROMAN VALIEV/ISTOCK/GETTY IMAGES

Telescope + eyepieces



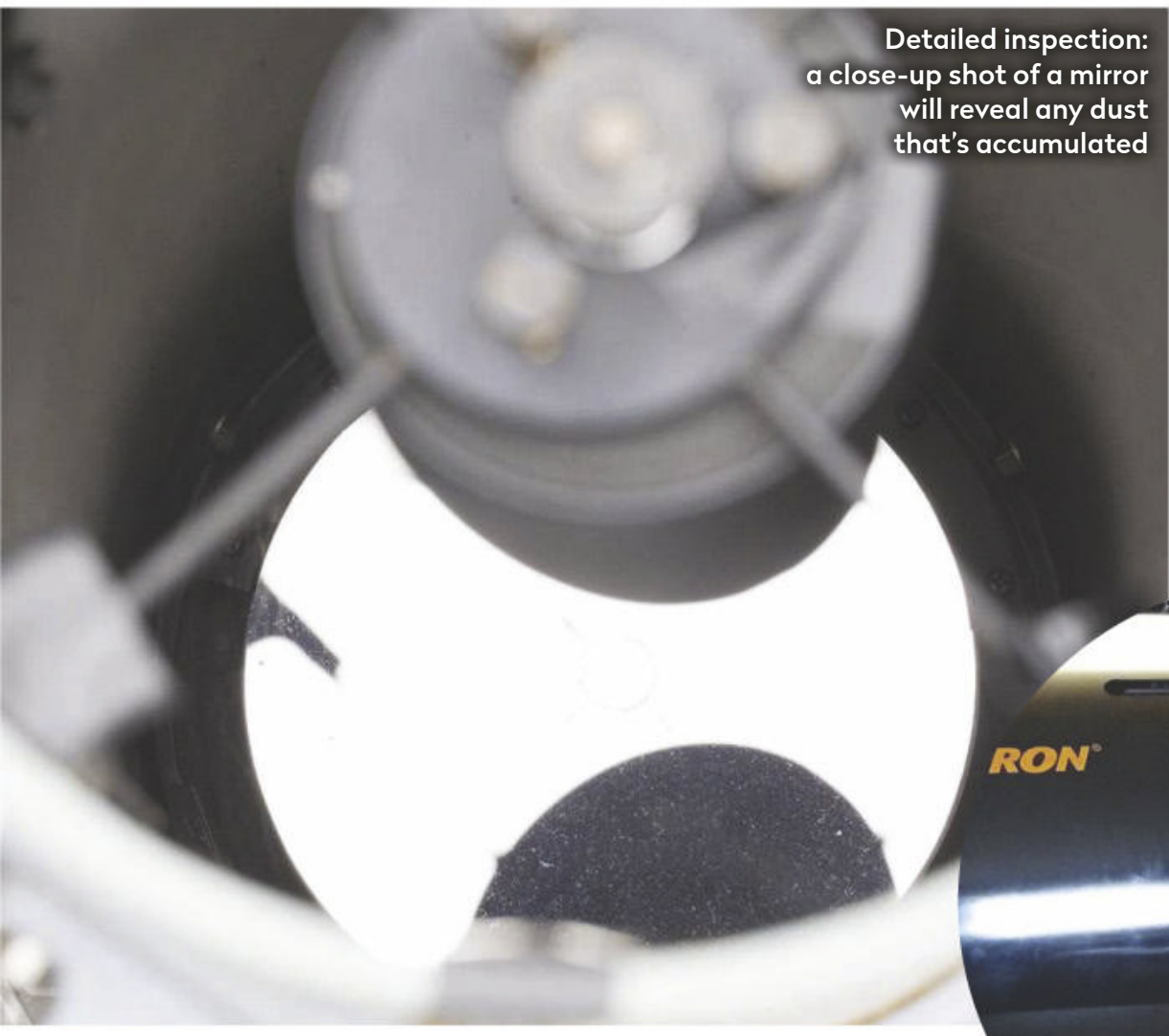
Peterborough
- Good condition
- Offers accepted

Contact seller



Telescopes

Check for wear and tear, then be sure to test your scope before you buy



Detailed inspection: a close-up shot of a mirror will reveal any dust that's accumulated

"Feel free to ask for close-up images to check for scratches or coating blemishes."

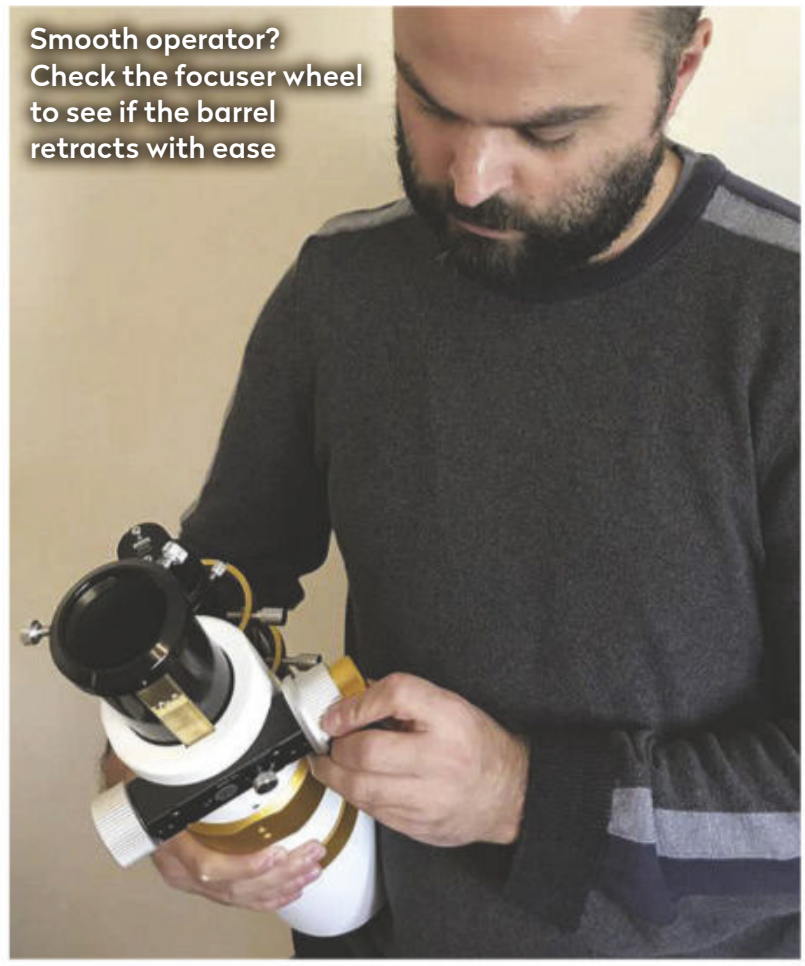
▼ **Superficial damage? Scratches usually won't make any difference to performance, but be on the look out for anything more substantial**

Telescopes are technically the 'optical tube assembly' (OTA) only, meaning that it doesn't come with a mount or tripod. When deciding whether to buy a second-hand telescope, there are many questions you can, and should, ask.

? Has there been any damage to the mirror or lens? Feel free to ask for close-up images to check for scratches or coating blemishes.

? Is the tube damaged? Look at pictures of the tube to see if the item has been handled properly. The odd scratch and scuff to the side is fine, but anything significant should be mentioned in the seller's advert – it could be a sign of misuse or damage. Get written confirmation that any 'wear and tear' you see has no effect on the optics.

? Are all caps and covers supplied? They should be as this ensures the telescope has been adequately stored, so check they're there.



Smooth operator? Check the focuser wheel to see if the barrel retracts with ease

? A question to ask yourself is, what are you going to use it for? If it's astrophotography, consider what images you're going to take through it. Field of view calculators will show how deep-space objects will look through different telescope and camera combinations to make sure it's appropriate.

If possible, it's best to pick up telescopes in person rather than trusting the fragile instruments to the whims of a courier company. As well as ensuring safe transport, you'll be able to test the equipment. You'll want to check that the focus wheel turns freely and the drawtube extends and retracts smoothly. If inspecting a refractor telescope, check the resistance screw underneath. Does this restrict and loosen the focus action correctly?

Also check the dust and lens caps fit snugly as this prevents moisture building up inside. Then remove the caps to look through the length of the refractor to check it's clear.

For reflectors, ask the seller's preferred collimation method; if they don't know how to collimate, it is likely alignment will be out. This isn't a problem, but collimation requires additional equipment and practice to perfect.

PETE LAWRENCE X 4, CHARLOTTE DANIELS, STEVE MARSH

Mounts

Former owners can be a valuable source of knowledge

▲ **Keep it steady: check for stability issues on any tripod you purchase**

◄ **Listen out: is the mount's slewing mechanism smooth and trouble-free or can you hear its gears grinding?**

Mounts are designed to be robust and a well cared for second-hand mount is a great purchase. Research is still important, as purchasing a first Go-To mount can be daunting: the mount is often more important than the scope itself – particularly for astrophotography. Assembling and working these the first time can also be a challenge.

Mounts are another second-hand item we'd most strongly suggest collecting if possible. Beforehand, find out where the mount has been stored. If left outside, internal mechanisms could be rusted, affecting performance. Also check whether it has been serviced, something more common for high-end mounts. This isn't essential, but servicing is recommended every couple of years to optimise performance. Ask the seller how the mount has been powered, ie via mains or a power pack; you may need to purchase adaptors if the seller isn't supplying them.

One of the most important attributes of a mount is its payload, the weight of the equipment it can carry, so work out if it will suit the telescope setup you plan to put on it. If you want to use a mount for imaging, a general rule is to take the mount's advertised payload and halve it; this will be your imaging payload.

When collecting, ask the seller in advance if they can demonstrate the setup so you can see how it works and if anything is missing. If the mount comes with a tripod, check the legs extend and tighten, and for signs of rust. Listen to the mount slewing to a target; does the action sound smooth or are the gears struggling?

Binoculars

Make sure you see lots of pictures before the seller posts your item

Daylight condition: the best way to check a binoculars' lenses is from a photo taken in the day

Because of their small size, binoculars can be couriered or posted if packed securely. While you would benefit from holding and looking through them in person, getting your eyes up close to an item during a pandemic is difficult to do safely. Getting lots of pictures of the product before payment and delivery is therefore advised. Check that all covers are provided, and whether it comes in a hard or soft case.

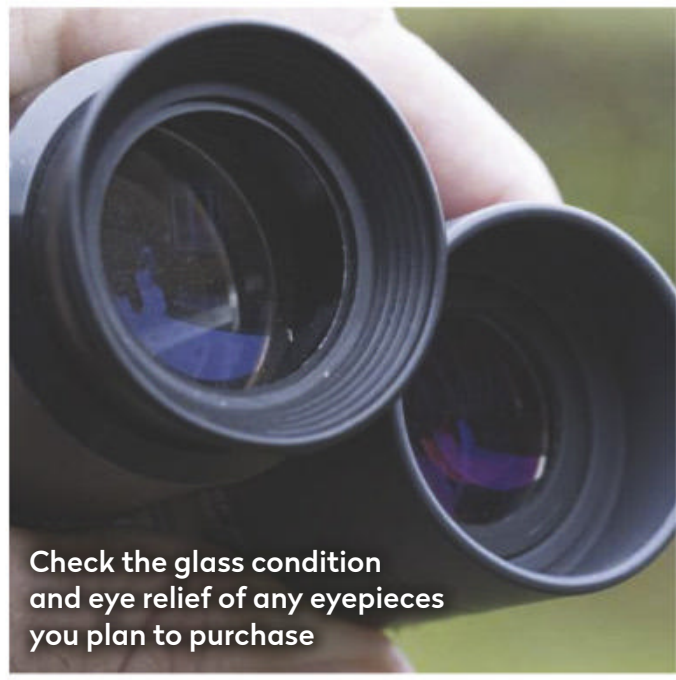
Much like a telescope, ask the seller for images of the lenses in good daytime lighting – are these clear? Don't worry about seeing dust as this is unlikely to impact your viewing experience. What you're looking for are coating blemishes or scratches on the glass. Ask the seller if there are any focus or usability issues. If the answer is vague, proceed with caution.

If you do manage to test the binoculars in person, try to find a distant object you can focus on. Can you adjust the focus correctly in both eyes to achieve a single clear image? Pay attention to how much resistance there is when you adjust the focus and if there is any haze affecting the optics. ►

Filters and eyepieces

Though small, these can end up being your most expensive pieces of kit

▲ Light matters: ask a seller for photos of the filters held up to the light



Check the glass condition and eye relief of any eyepieces you plan to purchase

The high quality glass needed for filters and eyepieces means they can be expensive. They are, however, easy to post so if the seller can confirm (via photos) that they come with dust-free covers and a hard case, these should be fine for delivery.

Filters are delicate and need to be handled with care, so they can be susceptible to damage which you'll need to check for. Obvious blemishes due to misuse can be highlighted in photos; it's perfectly acceptable to ask for close-up images of a filter held up to a light, to check for obvious signs of damage.

If you're buying filters for astrophotography, it's always good to see images the seller has taken using them, and know what type of camera has been used. If it's a clip-in filter, check in the photo that both tabs are intact and symmetrical – one hasn't been bent or warped. This could affect how well the filter fixes to the camera. For screw-in filters check that the threads are clear and not worn or damaged.

Solar filters should only be purchased from a trusted astronomy vendor; the slightest damage to these could cause irreparable damage to eyesight or imaging equipment, so avoid second-hand items.

For eyepieces, check the 'eye relief' on the manufacturer's website – for people wearing glasses this needs to be long enough to view through at a distance. Once again, ask for images of the glass in the eyepiece's lens elements to check for scratches.

Perfect fit? Filter screw threads need to be in good condition, or you may have problems fitting them

Where to buy second-hand astro kit

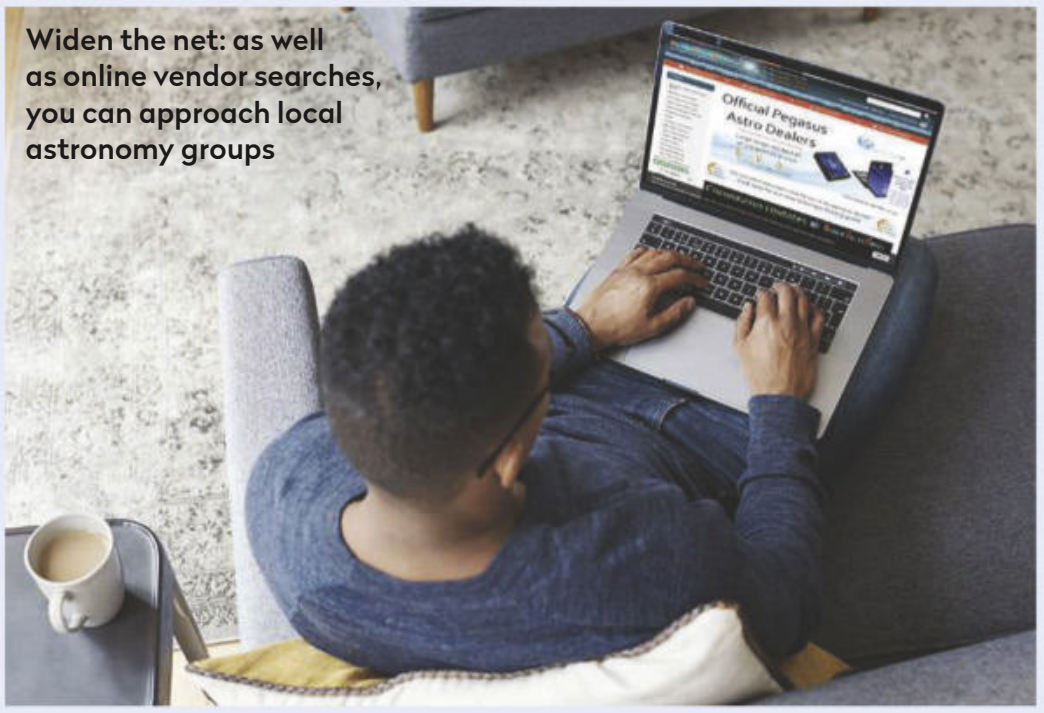
Thanks to the internet and social media, shopping for second-hand items isn't limited to one or two providers. It's worth checking in with your local astronomy groups as members regularly sell kit to each other, but other places to look for pre-owned astronomy equipment include:

VENDORS AND WEBSITES

- Rother Valley Optics: **rothervalleyoptics.co.uk**
- ENS Optics: **ensoptical.co.uk**
- Harrison Telescopes: **harrisontelescopes.co.uk**
- Astro Classifieds: **astrobuyandsell.com**

FACEBOOK GROUPS

- Astro Buy Sell and Swap UK Only
- Astro Buying & Selling
- Secondhand Astronomy Equipment UK



Widen the net: as well as online vendor searches, you can approach local astronomy groups

PETE LAWRENCE X 5, CHARLOTTE DANIELS, DEAN MITCHELL/ ISTOCK/GETTY IMAGES, ROTHERVALLEYOPTICS.CO.UK

Judging by results: ask to see an image produced by the camera you are wanting to buy...

Cameras

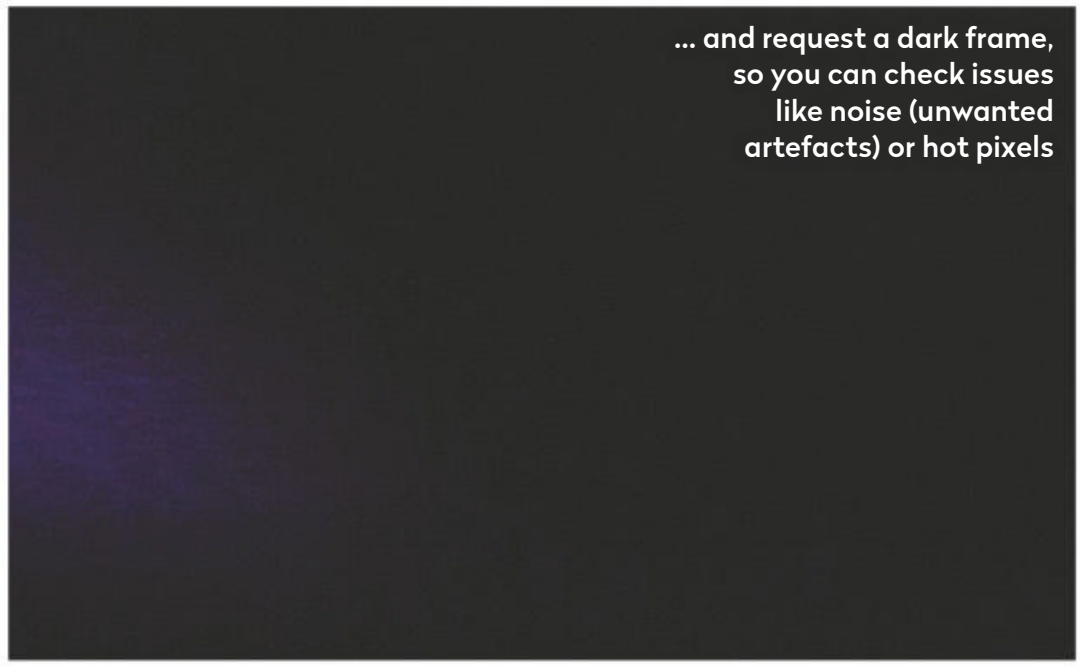
It's best to do some research ahead of time to make sure a camera fits your goals

There are many different types of cameras that can be used in astrophotography but these fall broadly into three categories; DSLR, CMOS and CCD cameras.

You can do some homework on the suitability of the camera for your setup – the sensor/pixel size against your telescope's focal length will affect the size of the image you'll get. There's a calculator at **www.skyatnightmagazine.com/astronomy-field-view-calculator** where you can enter your telescope and camera details to get a good idea of how your setup will perform. The wrong combination can negatively impact the quality of an astro image, so ensure the setup fits your goals.

Calibration frames are also important when assessing second-hand cameras. Feel free to ask the seller to send you a dark frame – these allow you to assess the amount of noise (unwanted artefacts), hot pixels or amp glow the camera provides. Dark frames can show if any light anomalies exist.

It's worth asking what settings the seller has used and seeing what images they've captured. For CMOS cameras, knowing the gain and offset settings they've used will provide a starting point as you experiment with the camera. For DSLRs, useful settings to know are preferred ISO and exposure times.



... and request a dark frame, so you can check issues like noise (unwanted artefacts) or hot pixels

◄ All clear: request a close-up of a CCD sensor to check if it's free of dust

Ask the seller to send a picture of the sensor to check that it's clear and free of dust. The sensor is easily accessed in a CCD, and for DSLRs can be imaged by selected the 'manual cleaning' setting.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

The fundamentals of astronomy for beginners

EXPLAINER EXTRA

The dramatic constellations of winter

Katrin Raynor-Evans takes a stargazing journey around the season's favourite targets

CHARTS BY PETE LAWRENCE, ALEXXANDAR/ISTOCK/GETTY IMAGES

As the Northern Hemisphere makes a transition from autumn to winter and leaves behind the season of mists and mellow fruits, darkness continues to lengthen and the familiar sights that winter skies have to offer are welcomed with open arms, like greeting old friends. The changing of the seasons brings a changing in the constellations – slowly nudged from east to west as we continue our journey around the Sun.

▲ Looking south: the night sky holds many of winter's most recognisable constellations

If you're a complete beginner to constellations, you may be wondering what they are. Quite simply they are grouped patterns of stars in our night sky. For thousands of years our ancestors looked to the sky, and observed and named them after animals, objects and mythological characters. You will need a bit of imagination as you try to identify each one as the constellation often looks nothing like its name!

In 1930, the International Astronomical Union formally recognised 88 constellations that can be

identified on the celestial sphere – an imaginary globe that surrounds Earth. Each constellation can be found using celestial coordinates: right ascension, and declination. These are similar to latitude and longitude, but don't worry, you can easily find the constellations just by recognising the pattern.

Some constellations are visible all year round and never sink below the horizon so you can see them whenever there is a clear sky. These are called circumpolar as they are close to the celestial poles, the imaginary point in the Northern and Southern Hemispheres where the line of Earth's axis extends out into space to meet the celestial sphere.

Colder, clearer evenings are perfect for enjoying the winter constellations as well as a few deep-sky objects like galaxies, star clusters and nebulae found within them. You can see these beautiful pin-prick patterns of light, hot fiery stars and clouds of dust and gas with your naked eye, using binoculars or a telescope. Best of all, you don't need to be in a completely dark-sky area to see them.

This short 360° tour highlights a handful of constellations that, with a clear horizon, are easy to spot after 20:00 UT and picks out what you may find hiding within them. If your horizon is obstructed by trees or buildings, you may need to wait a little longer until the constellation is higher in the sky. So, wrap up warm, grab this guide and step outside.

▲ **A close-up of the constellation of Orion, showing the location of the Sword**

Hunting Orion

If you were to ask any astronomer which winter constellation you should choose to kick off your stargazing journey, the answer will be Orion, the Hunter (see picture, above). Dominant against the darkness and easy to recognise, we can use it to navigate, so we'll begin here.

Orion can be found rising in the east after sunset and it's easy to identify from the three stars aligned in an almost straight line. These three stars – Alnitak (Zeta (ζ) Orionis), Alnilam (Epsilon (ε) Orionis) and Mintaka (Delta (δ) Orionis) – form Orion's Belt, which is an example of an asterism (a pattern of stars within a constellation). Orion is a winter favourite because of its two blazing, non-Belt stars – Betelgeuse (Alpha (α) Orionis), a bright orange star 1,000 times bigger than our own Sun, and Rigel (Beta (β) Orionis), a cooler blue supergiant – and its fantastic nebula.

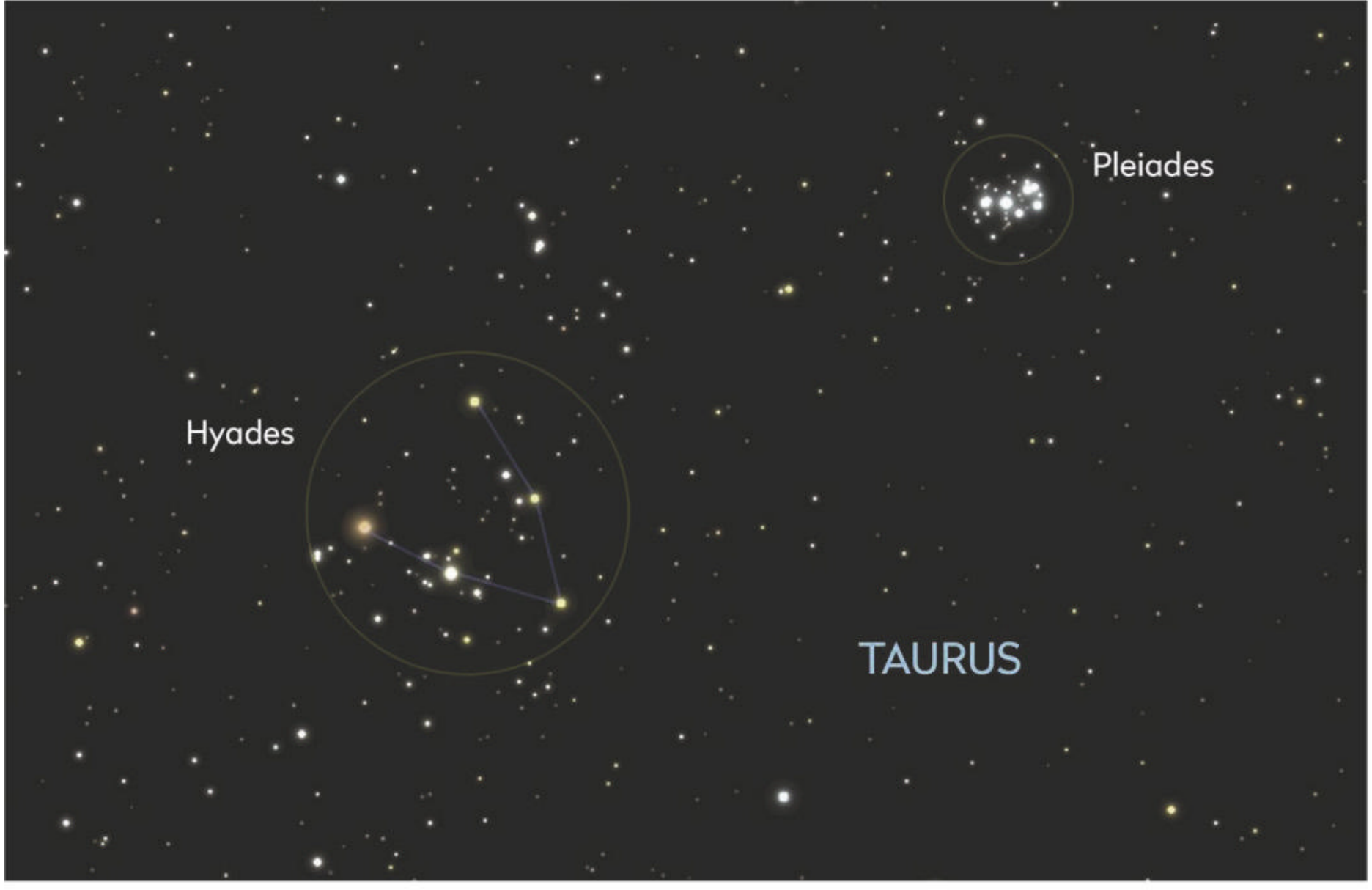
The Orion Nebula, M42, lies in the centre of Orion's Sword, a shorter line of three fainter stars that hangs down from the Belt. The nebula looks like the middle 'star' of the Sword to the naked eye, but a bit fuzzier than the stars above and below it. Composed of dust and gas and located 1,344 lightyears away, it is a famous nebula for naked-eye observing and perfect for beginners. A pair of 10x50 binoculars will enhance this diffuse cloud of dust and gas, while a small scope will bring out its darker and lighter patches.

▼ **To find Orion, look first for the distinctive line of three stars that forms its Belt**

The constellation of Gemini, the Twins, borders Orion on the Hunter's upper left shoulder. Gemini's two prominent stars, Castor (Alpha (α) Geminorum) and Pollux (Beta (β) Geminorum) are easily found: follow an imaginary line from Rigel to Betelgeuse and keep going until you reach two prominent stars positioned one above the other. They each form one of the heads of the Twins, which at this time of the year look like they are lying down with their feet near Orion's raised arm.

The Bull's Eye

To find the next constellation use Orion's Belt as a reference point again, and allow your gaze to drift upwards to the right of Orion's shoulder. You'll spot a bright orange star called Aldebaran (Alpha (α) Tauri), the brightest star in the constellation of Taurus, The Bull. Also known as the 'Eye of Taurus', this red giant is much cooler than our Sun. Taurus hosts two fantastic open star clusters and Aldebaran is positioned within one of them, the Hyades, which ▸



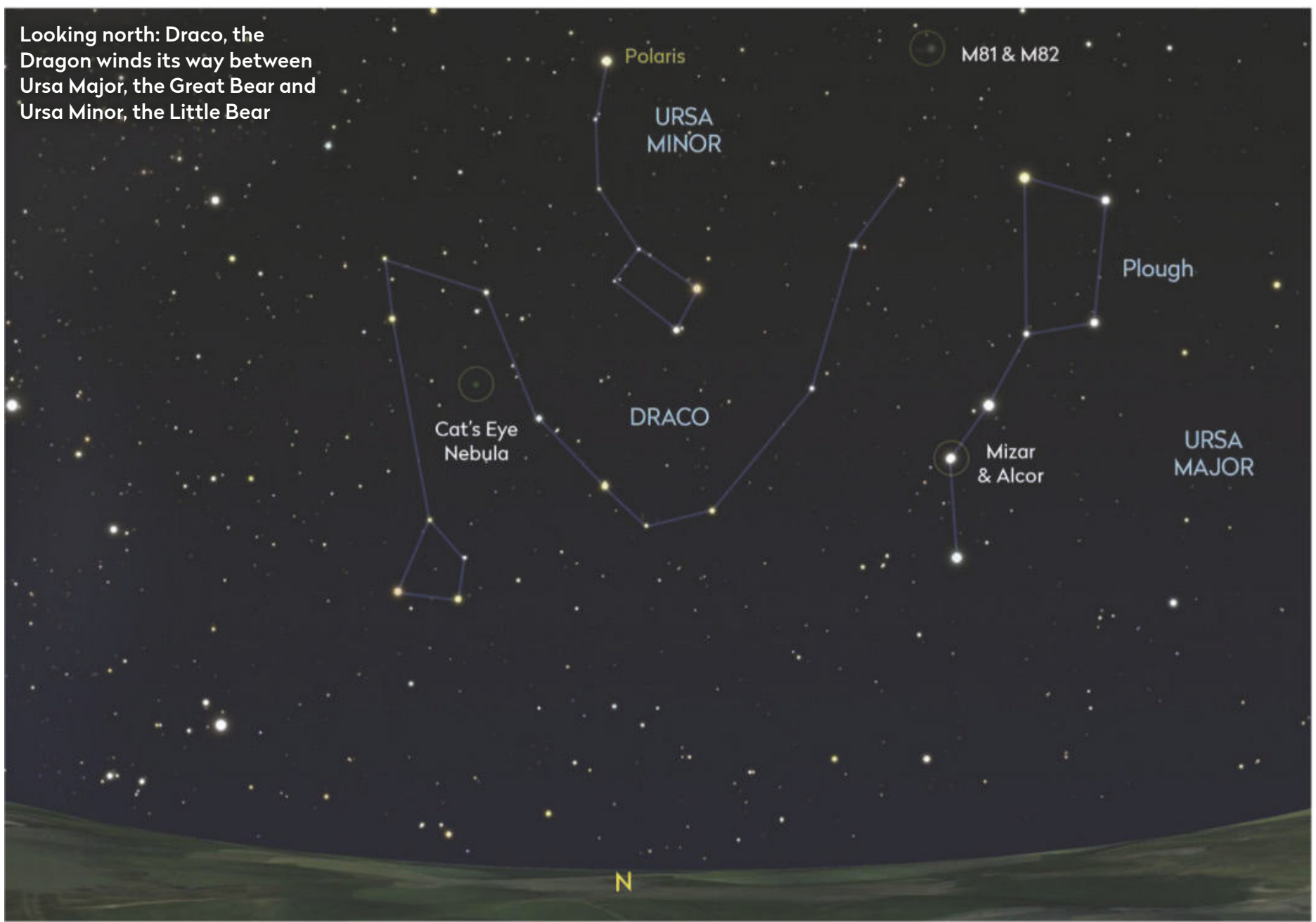
▸ appears like a 'V' shaped pattern of stars on its side. Located just above this is another cluster called the Pleaides (see picture, above), also known as the Seven Sisters because of the seven stars you can see with the naked eye. A pair of binoculars will reveal many more of the dimmer stars within each cluster.

▲ The Hyades and Pleiades open star clusters are naked-eye highlights in Taurus, the Bull

The Bears and a Dragon

Continuing with the tour, find Gemini again and sweep your eyes to the north. They will settle upon two constellations which you may well have spotted before – Ursa Major, the Great Bear and Ursa Minor, the Little Bear, whose tail ends with the North Star, Polaris (Alpha (α) Ursae Minoris). Draco, the Dragon winds its way between them both. Visible all year, these constellations hold some surprising targets.

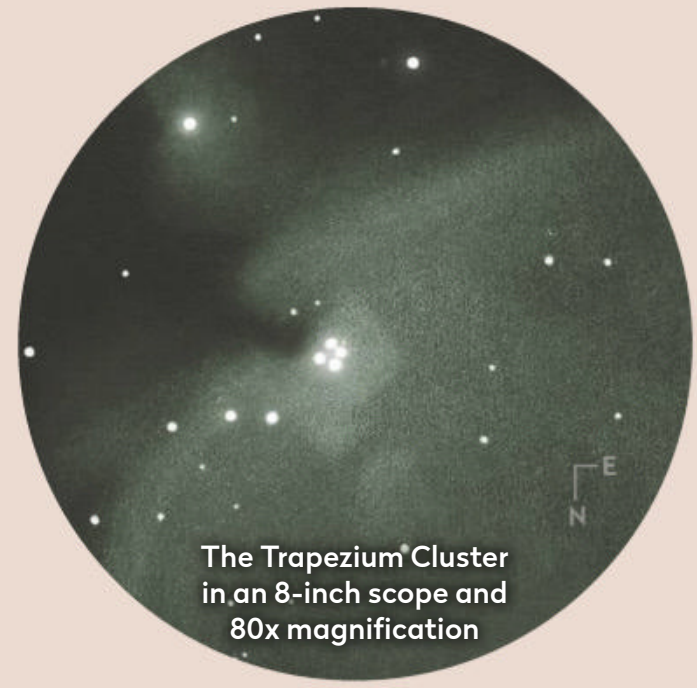
Ursa Major's back and tail make up that familiar asterism the Plough. At the bend in the Plough's handle lie Mizar (Zeta (ζ) Ursae Majoris) and Alcor (80 Ursae Majoris), a double star. Can you make them both out with your eyes alone? Mizar is brighter, so reach for your binoculars or scope if you struggle to see Alcor.



Top targets through the eyepiece

Here are 10 of winter's best constellation objects to observe with binoculars or a telescope...

The Pleiades seen in 15x70 binoculars



The Trapezium Cluster in an 8-inch scope and 80x magnification

WHAT TO SEE WITH BINOCULARS

The Pleiades, M45 – located in Taurus
This open cluster is the jewel in winter's crown; binoculars will bring many more of its icy blue stars into view.

Orion Nebula, M42 – located in Orion
A winter favourite, even a small pair of 10x50 binoculars will bring out this stellar nursery's grey-green nebulosity.

Alcor – located in Ursa Major
Grab your binoculars to see this binary star shining close to its brighter companion, Mizar.

Andromeda Galaxy, M31 – located in Andromeda
You can see the Milky Way's largest galactic neighbour with the naked eye, but binoculars will bring out its bright core.

The Double Cluster – located in Perseus
Located between Cassiopeia and Perseus, this sparkling Double Cluster will be brought to life through binoculars.

WHAT TO SEE WITH A TELESCOPE

Trapezium Cluster – located in Orion
Sitting within the heart of the Orion Nebula, the four stars in this open cluster are easily seen with 50x magnification.

Crab Nebula, M1 – located in Taurus
A telescope with 50x magnification will bring this nebula to life as a hazy patch of gas and dust through the eyepiece.

Bode's Galaxy, M81 and Cigar Galaxy, M82 – in Ursa Major
Telescopes with 50x magnification will bring out the spiral structure of Bode's Galaxy and the Cigar Galaxy's rod shape.

Pinwheel Galaxy, M33 – located in Triangulum
This face-on spiral galaxy is best seen with averted vision; a scope with 50x magnification is recommended.

M35 – located in Gemini
Viewed through a telescope on frosty nights this open cluster is a glittering treat; a magnification of 25x is recommended.

Katrin Raynor-Evans is an amateur astronomy writer and is the features editor for the Society for Popular Astronomy

Draco is a useful pit stop to locate the wonderful Cat's Eye Nebula, NGC 6543. This is not a naked-eye object, but larger telescopes will show the nebula as a blue-green disc. Keeping your gaze high and looking west from Polaris, navigate to the inverted 'W' or 'M' shaped pattern of stars; these five prominent stars are an asterism in the constellation of Cassiopeia, the Queen. Cassiopeia lies in the band of the Milky Way so, grab your binoculars and choose one of the 'W's five stars to focus on. The area of the sky around each one will open up and appear thick with stars.

A dance of stars

The final three constellations to enjoy are Andromeda, the Chained Princess; Perseus, the Greek Hero; and Auriga, the Charioteer. Once you have located Andromeda to the west of Cassiopeia, you can hop constellations with ease right back to Orion.

The not-so-hidden gem in Andromeda is the Andromeda Galaxy, M31, 2.5 million lightyears away. With dark-adapted vision, you can spot it with your naked eye in darker sky areas. A telescope will reveal its neighbouring galaxies, M32 and M110. Andromeda's brightest star, Alpheratz (Alpha (α) Andromedae), also forms part of the constellation of Pegasus, the Horse, which lies to the south of Andromeda.

Cast your eyes up from Andromeda to Perseus lying in wait overhead. Locate Algol (Beta (β) Persei), the demon star, the constellation's brightest member. The brightness, of this eclipsing binary multiple star system can fluctuate over just one evening as two of its members revolve around each other.

Finally, look to the lower left of Perseus to find Auriga, the Charioteer, a prominent constellation in the winter sky. Its startlingly bright shimmering star Capella (Alpha (α) Aurigae) is a real showstopper. Comprising two binary star systems, it is the sixth brightest star in the sky and the third brightest in the Northern Hemisphere.

The winter constellations are revered by astronomers, as they herald a season of long nights observing ahead. You will be astounded at the sights you can see from your own back garden, leaving you keen for spring to stay in the wings a little longer.

DIY ASTRONOMY

Set up your own meteor detection system

Connect a Raspberry Pi to a camera and help the Global Meteor Network with its research

All night long: your detection system will gather data on meteors (inset)

We all know about the big meteor showers such as the Geminids and Perseids, but Earth is also bombarded by much smaller meteors every night. Knowing more about these tiny pieces of space dust helps us to analyse meteor showers, sporadic meteors and fireballs, as well as increasing our knowledge of the risk to Earth from larger debris. For example, consider 'orbital resonance', which occurs when orbiting bodies exert periodic gravitational influence on each other: research has shown that fireballs from one branch of the Southern Taurid meteor shower debris stream are in 7:2 resonance with Jupiter. This supports a theory that asteroid impacts on Earth are not totally random and appear to have resonances too. Meteor analysis is vital to help our understanding of such potential risks.

One way that amateurs can help is by setting up a meteor detection system. A few years ago this was an expensive task, but now with some simple electronic parts it's much easier. These systems record the sky all night long, so even when you can't stay up late observing yourself, your camera will continue to record for you. And since the camera is running constantly you'll never miss any cloud breaks.

Mary McIntyre is an outreach astronomer and astro imager based in Oxfordshire

A meteor detection system captures both video and stills. The images and videos are not high resolution as the main goal here is scientific analysis of the data, but it's still great to have a visual record of events. Your data will be automatically uploaded to a global database, where it is combined with data from other cameras to work out the orbit, and often the origin, of a meteor; it may even be used to work out where a meteorite might have landed.

The data is used to monitor meteor shower rates and duration, accurately forecast the peak of the shower, as well as monitoring and predicting outbursts and plotting the radiant – the point at which the shower appears to originate as seen from Earth. These systems help to track minor meteor showers, sporadic meteors, fireballs and new showers. Once your camera is set up it all happens automatically, but you can do your own analysis of the data as well.

Getting ready

The system we are setting up runs on a Raspberry Pi and uses a cheap security camera module. It uses the Raspberry Pi Meteor Station (RMS) software, which is free to download from the Global Meteor Network (GMN) at **bit.ly/3pBfdZe.** Before you begin, download the RMS disk image (a copy of the operating system (OS)) from the URL above, unzip it to a folder and burn the image to the micro-SD card using balenaEtcher, or a similar tool for burning disk images. When you boot up the Pi it will automatically install the OS software ready for you to configure it. You will also need a camera code before you begin, so contact the GMN team via email, at **denis.vida@gmail.com**.

What you'll need

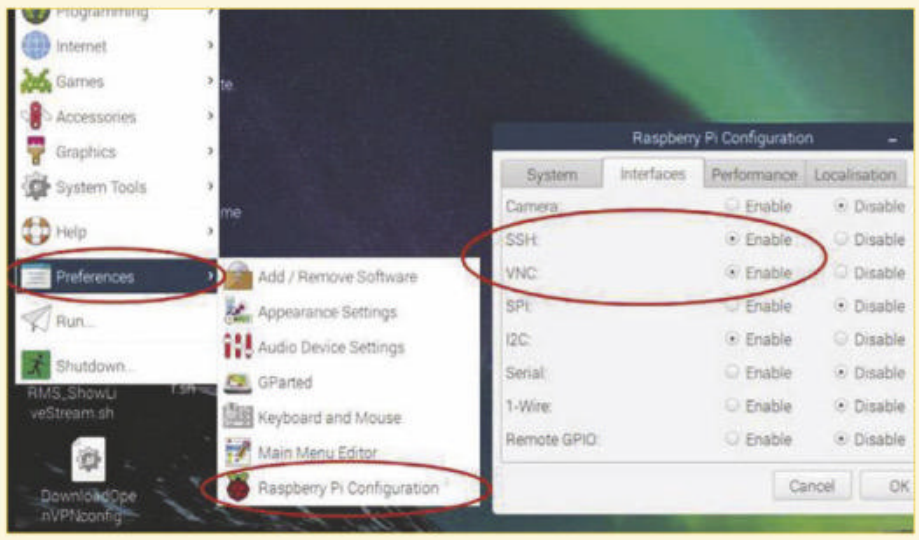
- Raspberry Pi 3B+ computer with a case, fan and power supply
- 128GB class 10 micro-SD card
- IMX291 bare-bones camera module with power cable and 5V power supply
- Security camera housing and mounting bracket
- Two (PoE) injector cables, plus an ethernet cable that's long enough to reach from the camera to the Pi when the camera's mounted

ALL PICTURES: MARY MCINTYRE

Step by step

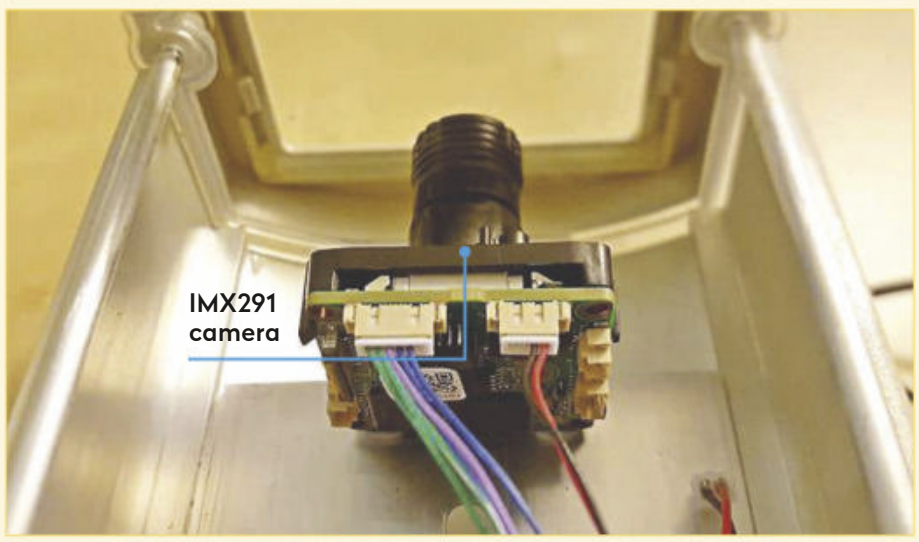
Step 1

Insert the micro-SD card into the Pi, connect a keyboard, mouse and monitor and start it up. You'll find that the RMS software will start automatically; work through the configuration script, entering your location and camera code when you're prompted.



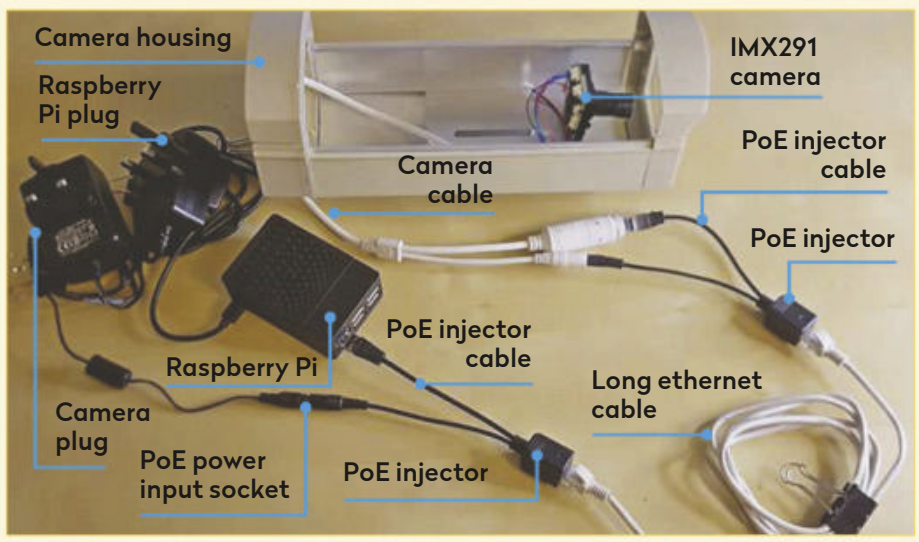
Step 2

Click the 'Raspberry icon' at the top left and select 'Preferences > Raspberry Pi Configuration'. On the 'Interfaces' tab, ensure that 'SSH' and 'VNC' are enabled. Close the configuration tool, then click the 'Wi-Fi icon' on the menu bar and connect to your Wi-Fi.



Step 3

To set the camera and case up, begin by feeding the camera cable through the security camera housing. Then connect the PoE (power-over-ethernet) injector cable to it. Next, fit the camera inside the housing, close to the front glass; use hot glue, but don't seal just yet.

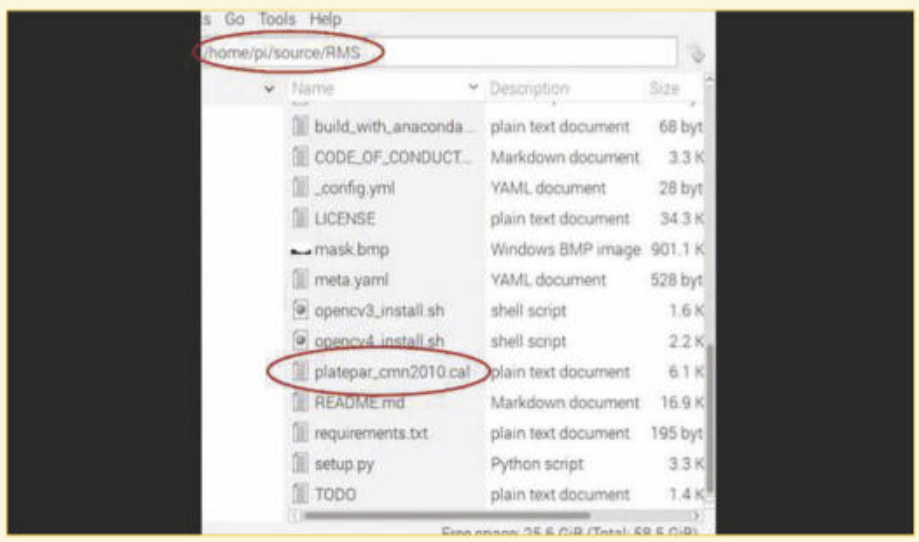


Step 4

Now plug the other PoE cable into the Pi's ethernet port and then, using an ethernet cable, connect the Pi to the camera by connecting up the PoE injector cables. Meanwhile, plug the camera power supply into the PoE power input socket.

Step 5

On the Pi screen, double click on 'RMS_ShowLiveStream.sh' and select 'Open in terminal'. Use the live view to help you focus the camera, then close and seal up the camera housing. Disconnect and mount the camera on an outside wall pointing it up about 45°.



Step 6

Power up the Pi, and it will now run automatically. Contact Denis Vida (details opposite) to create a 'platepar'; copy this to the Pi and your camera will be ready to go. After the first night's run, your system will upload data to the Global Meteor Network.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

How to image lunar craters

Discover why it's never been easier to photograph the Moon's crater-ridden surface

The Moon is a pockmarked lump of rock – battle scarred from a multitude of past impacts. Some of these were so large that they deformed the lunar crust, depressing and cracking it so the resulting depressions infilled with lava. These huge basins form the lunar seas or maria – and they can be extensive in area.

▲ **Complex regions, such as the area around the crater Theophilus (top, centre) make excellent imaging targets**

Shooting the Moon

As well as the large basins, there are many craters of all shapes and sizes that make great imaging targets. The larger ones can be imaged with basic kit like a smartphone; all you need to do is to point the phone's camera down the eyepiece of a telescope. Known as afocal imaging, this technique produces good results, often exceeding the results that used to be produced by coupling a DSLR to a scope.

As afocal imaging requires you to point your scope at the Moon, a tracking drive is recommended as it alleviates the need to continually shift the scope's position to keep the Moon in view; you'll have enough to do lining up the camera. Focus is critical and it needs to be done for corrected vision; if you wear glasses, focus with them on. Use a low- to mid-power eyepiece and centre the Moon in the field of view.

Next, activate your smartphone's camera. Most camera apps have a pro or manual mode that allows you to control the camera settings, which is great if you're feeling confident. If not, leave the camera on automatic. The Moon is bright enough to activate the camera app's auto-settings and 75 per cent of the time the values selected will work just fine.

It helps to develop a lining-up technique. One way is to hold the phone's camera some way off the eyepiece. You'll need to be able to see the eyepiece with a bright light (the Moon) coming from it. Then, slowly but surely, move towards the eyepiece keeping the bright area in view. It can take a while to get this right, and bear in mind you need to a) keep the camera flat to the eyepiece and b) eventually press the shutter button. The second step is easier if you use a remote shutter release. A smartphone's wired headphones often mimic this action; plug them in and press the volume up button.

The best crater images are obtained using a high frame rate planetary camera attached to the eyepiece end of a telescope. Here, there are certain techniques which will give you optimal results, and we've shown some of these in our step by step guide (opposite). How small you can go in terms of crater diameter is determined by the size of your scope; the greater the aperture, the smaller the feature you can resolve. The stability of the atmosphere will also have an effect, the best results being achieved when seeing is steady. Forward planning can help here (see opposite, Step 4).

With so many lunar craters to choose from, and the earlier phases of the Moon being well placed in the winter and spring sky, this month is a great time to get acquainted with our nearest neighbour in space using whatever equipment you have to hand.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: Telescope on a tracking mount, smartphone for afocal-imaging, DSLR/ MILC camera, high frame rate planetary camera, optical amplifier, red or infrared pass filter

✉ **Send your images to:**
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step

STEP 1

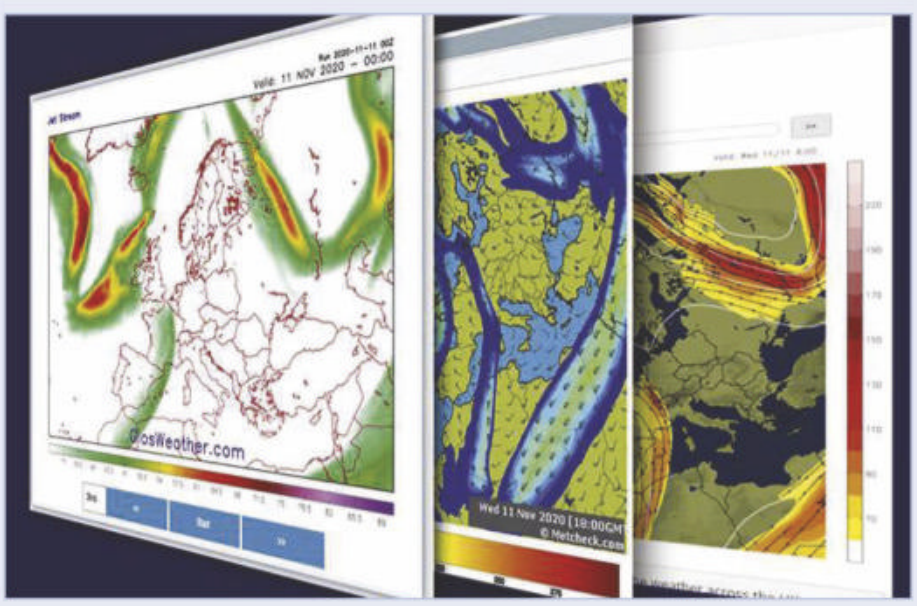
The simplest method for imaging the Moon with a scope is to point a camera down the eyepiece using the technique of afocal imaging (as described opposite), which works well for smartphones. Getting everything lined up can be tricky, so practice is advised. Also, it's best to image the Moon when it's not close to full phase.

STEP 2

If you have a DSLR or MILC camera, fit an adaptor onto the connecting ring of the camera's body – where the lens would usually connect – and attach an eyepiece barrel for insertion into your scope. A 2-inch barrel will avoid light cone clipping, which can lead to vignetting (a darkening at the edges) in images.

STEP 3

For high-resolution crater imaging, a high frame rate planetary camera is best. Controlled by an external computer such as a laptop, modern high frame rate cameras can typically capture from many tens to hundreds of frames per second. This helps to combat seeing-related issues, such as atmospheric distortions.



STEP 4

Bear in mind that seeing degrades with low altitude and the Moon appears highest when due south. As wind direction affects low-level seeing, note the seeing for different wind directions to predict when conditions may be steady. To avoid the jet stream use a forecast service (Google: 'jet stream forecast').

STEP 5

Use a Barlow or other such optical amplifier to increase the image-scale. The optimum focal length to aim for under average seeing conditions is given by 825 x Ps, where 'Ps' is the size of your camera's pixels in microns; under good to excellent seeing use 2060 x Ps. Use an optical amplifier to get you close to these values.

STEP 6

Longer wavelengths are less affected by seeing. Imaging with a mono camera through a red or infrared pass filter may produce steadier results. Some colour cameras have excellent infrared sensitivity and can be used this way too. Aim to capture at least 1,000 frames. Process in a stacking program and tweak the result.

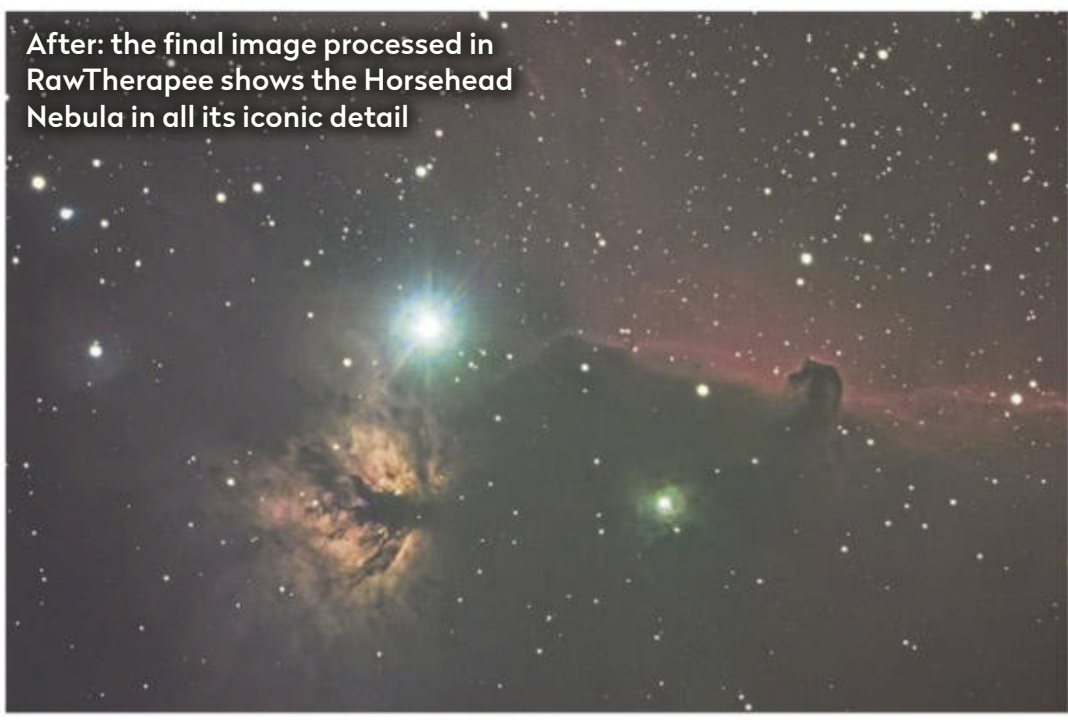
Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Bring out detail in images of nebulae

Transform your images of these faint targets from dark RAW captures using free software

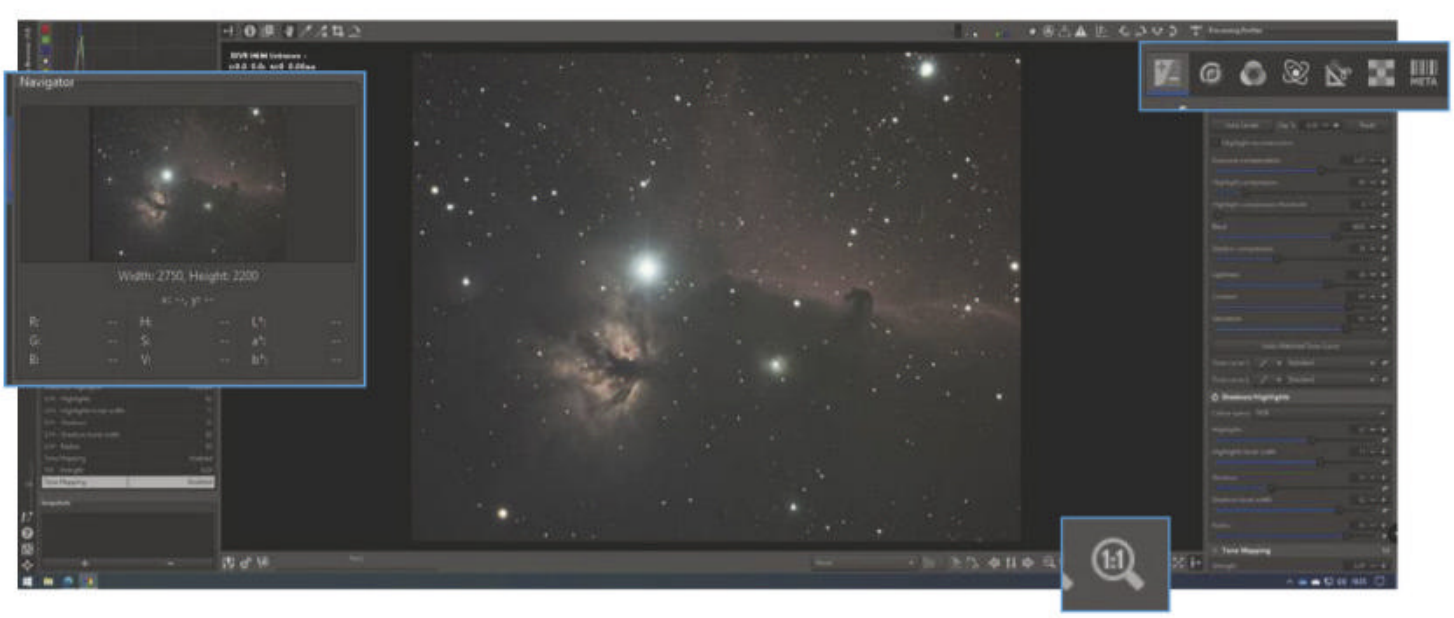
Before: the workflow began with a TIFF file consisting of RAW images stacked in DeepSkyStacker



After: the final image processed in RawTherapee shows the Horsehead Nebula in all its iconic detail

DSLR astrophotos should be shot in RAW format because this delivers the best editing capability; the images aren't altered by the camera before being opened in processing software. The program we're using on our RAW files this month is RawTherapee, a free editing software designed to handle such unaltered data. It's similar to Adobe Lightroom, in that you can make adjustments to one image and then apply those settings to others. It also has some interesting routines to enhance deep-sky astrophotos, including the ability to manage light and dark contrasts, reduce noise (unwanted artefacts) and bring out detail. Most adjustments in RawTherapee are made by moving sliders; if you hover a mouse cursor over most of the slider names it will give handy explanations for what they do. In our example, we are using RawTherapee on an image of the Horsehead Nebula to enhance the detail in this iconic nebulosity.

To begin, we use a TIFF file (see image, above, left), which consists of RAW images stacked in DeepSkyStacker. After opening RawTherapee, locate the file using the 'Folder' window on the left-hand side and double click it. This opens it in the central window (see Screenshot 1, below). A 'Navigator' window can be seen to the left of our image. If you



▼ Screenshot 1: under the 'Exposure' menu, 'Tone Mapping' increases detail and structure, while colour and tone can be edited separately in 'L*a*b* Adjustments'

ALL PICTURES: CHARLOTTE DANIELS

zoom in to make adjustments, this window shows how changes will affect the whole picture. The main adjustment menus are located on the top right-hand side (as highlighted in Screenshot 1). The menu icons are, from left to right, 'Exposure', 'Detail', 'Colour', 'Advanced', 'Transform', 'Raw' and 'Metadata'. We'll focus on the first four menus for adjustments.

Bringing out details

Clicking on the 'Exposure' menu icon brings up submenus below it. These are used to increase the brightness of the image and boost the contrast between highlights and shadows, which will help bring out details. The 'Exposure' submenus include 'Shadows/Highlights'. This submenu has a power symbol on the left, which means any changes made will only appear if the submenu is switched on by clicking this icon. Once the power symbol is clicked, the 'Highlights', 'Shadows' and 'Radius' sliders within the submenu to the right can be moved, and the nebulae start to appear as adjustments are made.

It's worth noting that some submenus in 'Exposure', such as 'Tone Mapping', also have '1:1' next to them. With these submenus you need to zoom in to see the changes made. This is achieved by clicking the '1:1' icon at the bottom right of the image.

Further adjustments in the 'Exposure' menu are made by adjusting sliders in the 'Tone Mapping' and 'L*a*b* Adjustments' submenus. The 'Tone Mapping' functions are used to increase detail and structure in dark areas, while 'L*a*b* Adjustments' allows colour and tone to be edited separately. In 'Tone Mapping', increase the 'Gamma', 'Scale' and 'Reweighting Iterates' sliders, before moving the 'Chromaticity' slider under the 'L*a*b Adjustments' submenu.

Now details are starting to emerge, but the nebula's colour could do with more of a boost. To do this, scroll back up and click on the 'Colour' menu. The 'Vibrance' submenu allows you to increase colour saturation in the image by moving the slider for 'Saturated Tones' (see Screenshot 2, below, top).

Scroll back up again to the main menu icons and click 'Advanced' to see its submenus. A useful application in 'Advanced' is the 'Wavelet Levels' submenu, which will enhance details in an image if used carefully. Decreasing the 'Strength' by moving its slider to the left, and increasing the 'Wavelet Levels' will improve the nebulous detail within the image; remember to do this with '1:1' viewing mode activiated.

Finally, move to the 'Detail' menu icon on the right-hand side of the screen, where you'll find the 'Noise Reduction' and 'Impulse Noise Reduction' submenus (see Screenshot 3, below). Both need to be viewed in '1:1' to see adjustments clearly. The 'Luminance' and 'Detail recovery' sliders perform significant noise reduction, getting rid of unwanted artefacts, but need to be handled carefully to avoid losing detail or structure in the nebulae. Then, once you're happy with the adjustments, click on the 'Save' icon at the bottom left of the screen.

RawTherapee has plenty of other functions worth investigating and taking time to explore. Our final Horsehead image (see opposite, top right) came out clear, with bright objects like star Alnitak (Zeta (ζ) Orionis) and the Flame Nebula both well handled.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

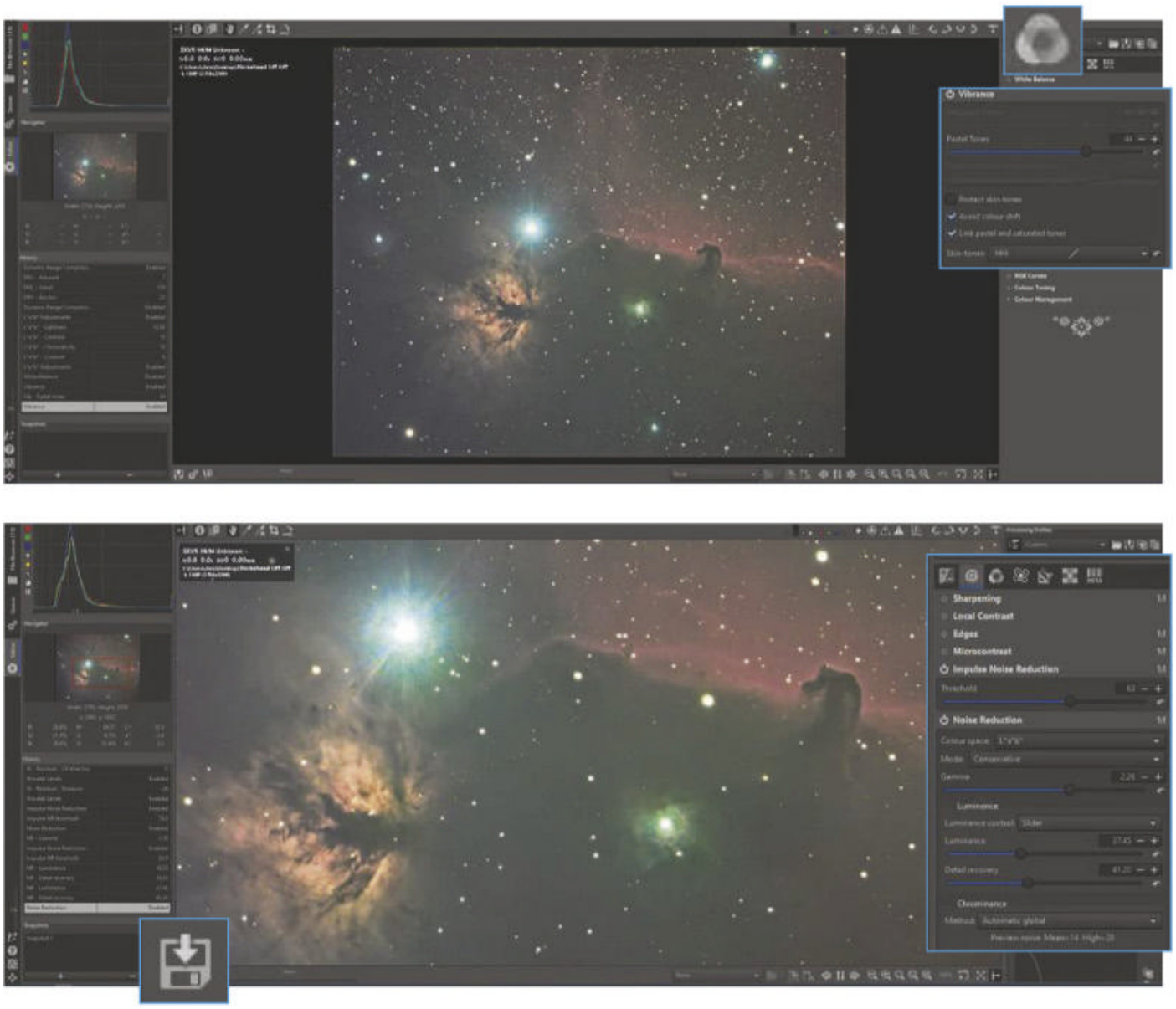
3 QUICK TIPS

1. Leave 'Noise Reduction' sliders until last and concentrate on the details in your image first.

2. Gone too far? Undo your adjustment by clicking the curved arrow next to the slider (see Screenshot 3).

3. Make very small adjustments with the sliders and keep an eye on the 'Navigator' window as you do so.

▼ **Screenshot 2: under the 'Colour' menu, the 'Vibrance' submenu allows us to increase colour saturation by adjusting the 'Saturated Tones' slider**



▲ **Screenshot 3: Use the 'Luminance' and 'Detail recovery' sliders to remove noise (unwanted artefacts)**

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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▽ Mars before, during and after opposition

Keith Johnson, Ferryhill, County Durham, 31 August–30 October 2020

Keith says: "I was so lucky to capture so much Mars data. Having an observatory really helps, as I could quickly slew to the planet to assess the seeing conditions. The weather was not good and the jet stream over the UK has been having a terrible effect, but with sheer determination I still managed to capture something worthwhile."

Equipment: ZWO ASI 290MM mono camera, Celestron 9.25-inch Schmidt-Cassegrain scope, Sky-Watcher EQ6 Pro mount **Exposure:** R 11.0ms, gain 199, G 12.7ms, gain 251, B 21.3ms, gain 223 **Software:** PIPP, AutoStakkert!, RegiStax, Photoshop, GIMP

Keith's top tips: "For planetary imaging, I'd recommend: 1) a dedicated USB 3.0 high frame rate colour camera with a small sensor, 2) a large aperture f/10 telescope (Schmidt-Cassegrains are popular but will need a suitable mount; check its collimation prior to each imaging session), 3) if visible, our Moon is ideal for focusing, for assessing the seeing conditions and planning imaging sessions around good jet stream forecasts."

△ NGC 6188, The Dragons of Ara

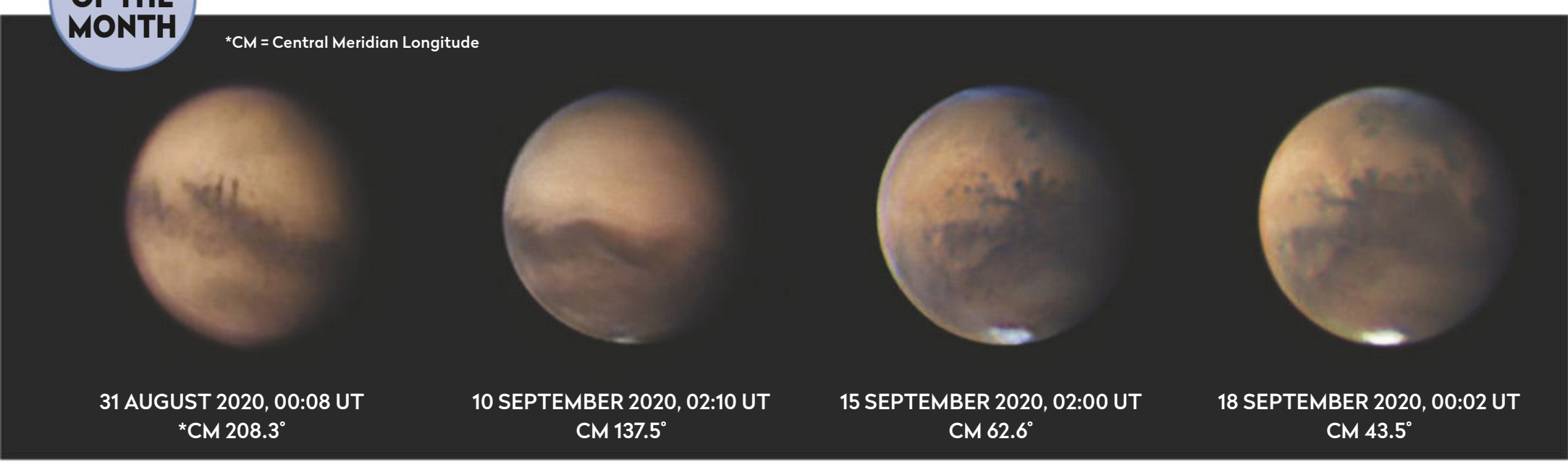
Shawn Nielsen, remotely via Siding Spring Observatory, Australia, March 2016 and October 2020

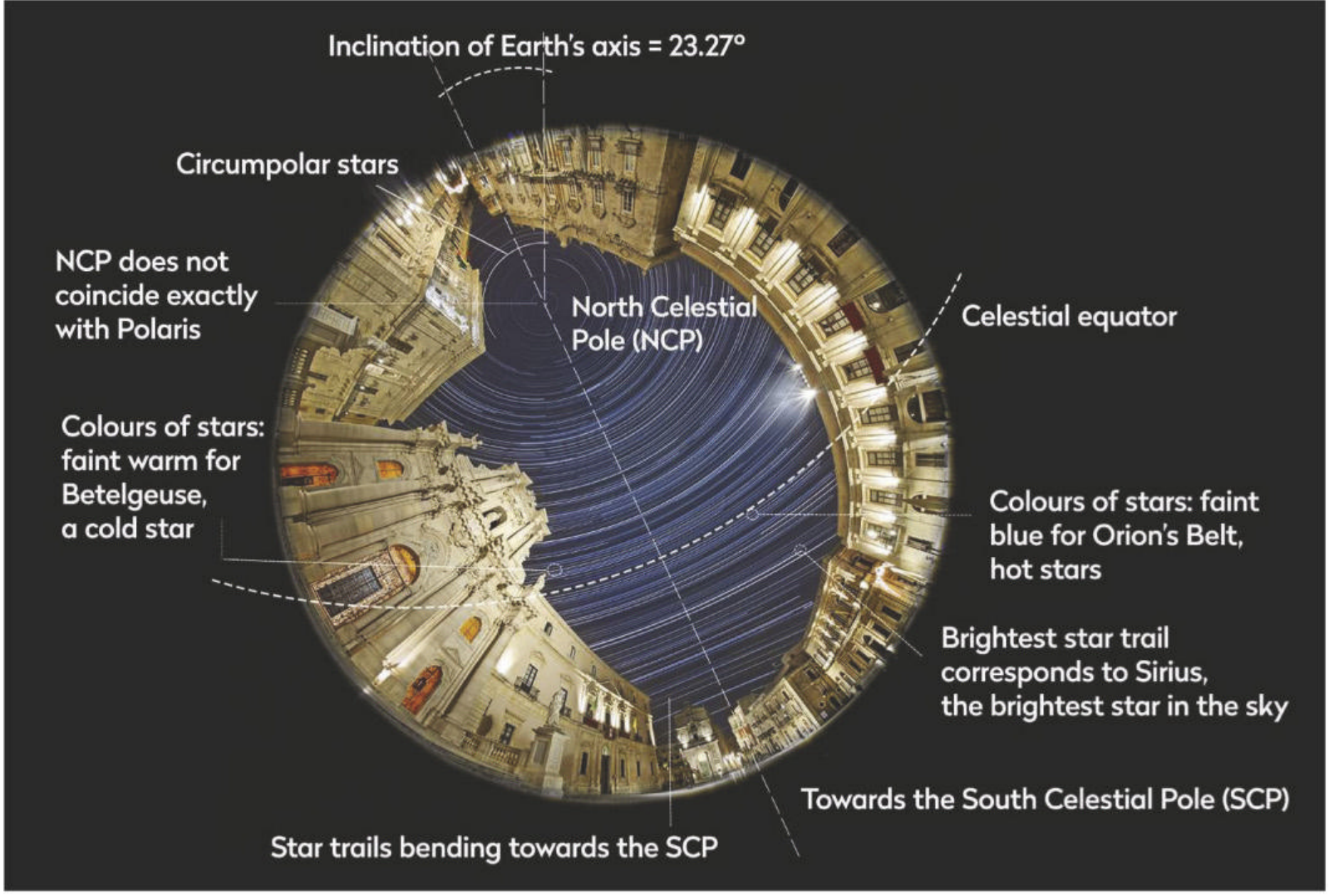
Shawn says: "COVID-19 has afforded many of us more time to spend on learning something new – in my case, new techniques in PixInsight for reprocessing this data from 2016. I was able to really improve the colours and increase the depth."

Equipment: SBIG STL-11000M camera, Takahashi FSQ-106ED refractor, Paramount ME EQ mount **Exposure:** Ha 12x 5', OIII 12x 5', SII 12x 5' **Software:** PixInsight

PHOTO OF THE MONTH

*CM = Central Meridian Longitude





△ Star trails over the Piazza del Duomo

Dario Giannobile, Syracuse, Sicily, 7 and 8 December 2018

Dario says: "The most complicated thing was watching the camera all night long in the middle of the cold, crowded square. Post-production was long too, as I had to merge different layers in the HDR image to recover the highlights."

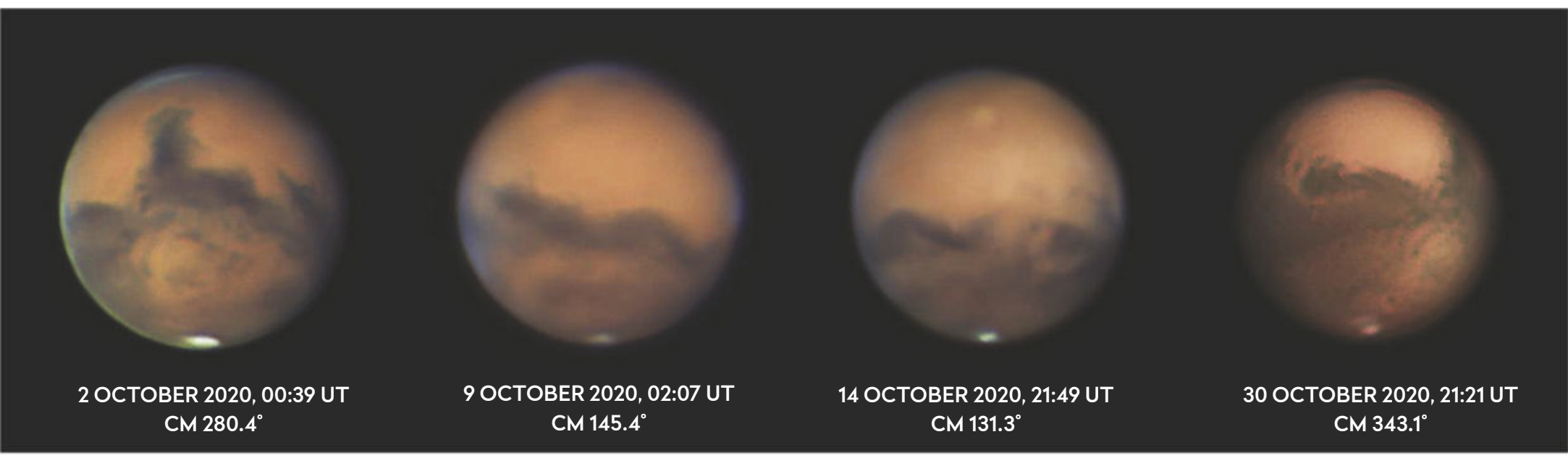
Equipment: Canon 6D, Canon 8–15mm lens, Manfrotto tripod
Exposure: stars: ISO 200 f/5.6, 30"; landscape: HDR, 30" to 0.25", 7.5h total
Software: Photoshop

◁ Mineral Moon

Treasa Giblin Frazer, Lifford, County Donegal, Ireland, 7 October 2020

Treasa says: "I've always wanted to try to capture the colours associated with the Moon's mineral deposits. It's always fascinated me."

Equipment: Canon 6D DSLR camera, Sigma 150–600mm lens, Manfrotto 055 tripod
Exposure: ISO 320, f/11, 1/400"
Software: Sequator, Photoshop



◁ Daytime lunar occultation of Venus

Aris Bottas, Brussels, Belgium, 19 June 2020

Aris says: "The Moon and Venus, as thin crescents, a few minutes after the reappearance of the planet after its occultation by the Moon. Clouds had spread in the sky, bringing a more ethereal view to this encounter."

Equipment: Canon 6D MK II DSLR, Celestron 9.25-inch Schmidt-Cassegrain, Sky-Watcher HEQ5 mount **Exposure:** ISO 100 f/10, 1/320 " **Software:** Photoshop

▽ The Andromeda Galaxy

Vicki Pink, Southampton, 21 September 2020

Vicki says: "This is my first go at capturing the Andromeda Galaxy with two of its 13 dwarf galaxies, M32 and M110. It was not an easy one to process: it took me weeks, but I'm super pleased with the colours."

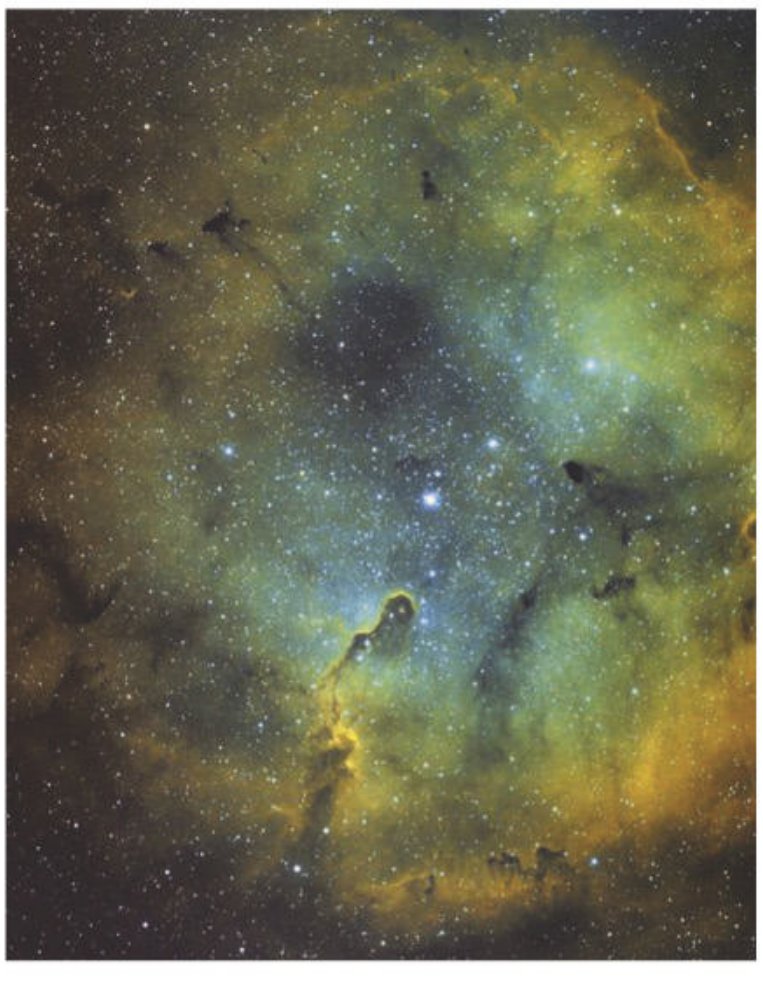
Equipment: Altair Hypercam 183C camera, Sky-Watcher 72ED Evostar refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** 5.5h total **Software:** SharpCap, Astro Pixel Processor, Photoshop

△ ISS zips across the Moon

Andrei Dumitriu, Bucharest, Romania, 1 November 2020

Andrei says: "I've been chasing this portrait for almost three years. I've had so many failures, that when I captured this, I poured myself a glass of champagne when I got back home to celebrate!"

Equipment: ZWO ASI 178MC colour camera, Orion ED80 apo refractor, Sky-Watcher Star Discovery mount **Exposure:** 0.5ms, gain 150 **Software:** FireCapture, AutoStakkert!, RegiStax, Photoshop



◁ Elephant's Trunk Nebula and IC 1396

Chris Callaway, Leicester, 20 and 21 September, 3 November 2020

Chris says: "The Elephant's Trunk produces good results in narrowband and I was pleased with the outcome from my five hours of data."

Equipment: Atik 16200 mono camera, Takahashi FSQ-106ED refractor, Paramount MyT mount **Exposure:** 30x 10' **Software:** Astroart, Photoshop

△ Milky Way over Galloway

Rod Armstrong, Coo Palace near Borgue, Galloway, 13 September 2020

Rod says: "The Milky Way seems to emerge from a tower in the perimeter wall of the property we were staying in. Saturn and Jupiter appear low down, with Altair at the top right."

Equipment: Sony Alpha 7 II camera, Zeiss Batis 18mm lens, Sky-Watcher Star Adventurer mount **Exposure:** ISO 800, f/2.8, 122"' **Software:** Photoshop

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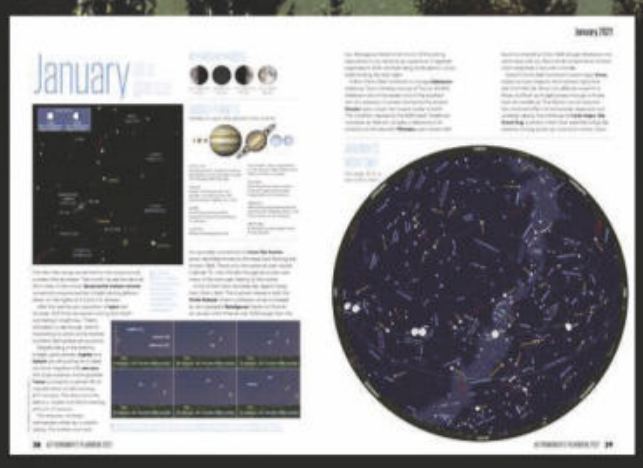
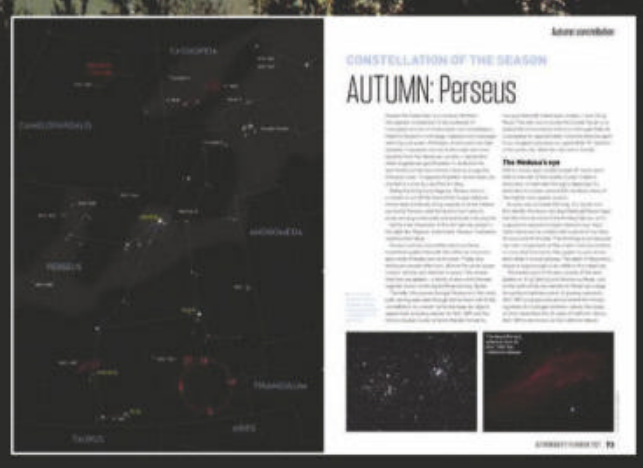
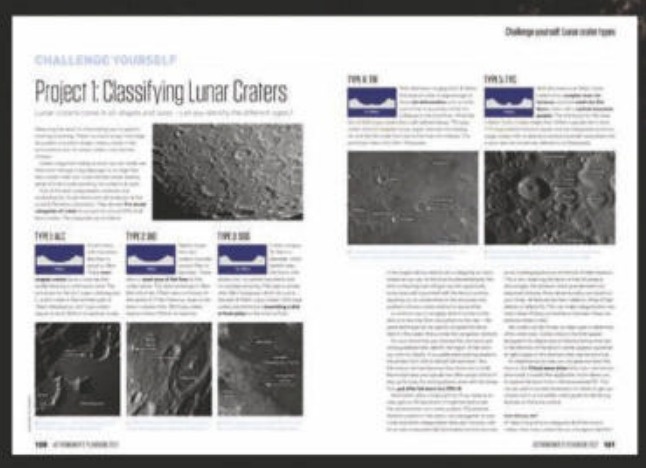


Our month-by-month guide and detailed star charts reveal what to look for and when, from stars and planets to Moon phases and more.



Get to know the stand-out constellations of each season, as we highlight their brightest targets and how to best observe them.



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★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

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FIRST LIGHT

William Optics
Zenithstar 61 II APO with UniGuide guidescope

A compact and light telescope setup for wide-field viewing and astrophotography

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** ZS61-II: £499.99; 50mm UniGuide guidescope: £125
- **Optics** Two-element, air-spaced apochromat (FPL-53 glass)
- **Aperture** 61mm
- **Focal length** 360mm (f/5.9)
- **Focuser** Dual-speed, rack and pinion, 2-inch barrel with 1.25-inch adaptor
- **Extras** Soft carry-case
- **Weight** ZS61-II tube only: 1.5kg; UniGuide guidescope: 0.5kg; fully assembled: 2.66kg
- **Supplier** Rother Valley Optics Ltd
- **Tel** 0190 977 4521
- **www.**rothervalleyoptics.co.uk

We could sum up the William Optics Zenithstar 61 II APO refractor as tiny and serious or seriously tiny; it's a small, portable instrument with a 61mm air-spaced, colour-corrected doublet lens, which definitely packs a punch, especially when used for astrophotography.

Externally, it's an attractive telescope that feels well made; attention has been paid to creating a visually attractive product. The main tube is white with a black clamping ring and focuser barrel, while a choice of colours – grey, gold or red – is used on the dust cap, dew shield, eyepiece clamp and mounting bar. If you decide to add on the optional UniGuide guidescope, this can be purchased with a matching colour as well.

The ZS61-II's 61mm objective lens has a focal length of 360mm, giving it a mid-range focal ratio of f/5.9. Being so small and portable, this wide-field scope is ideal for capturing views of the star fields and nebulae that are visible from dark-sky locations. The scope can also be used for taking photos of the Moon and planets and – with safety precautions adhered to and a suitable filter – the Sun; just don't expect detailed close-ups with such a short focal length. It would be ideal for eclipse chasing, however, as its naturally wide-field coverage is ideal for the expansive nature of the Solar corona during totality.

Visual testing

During visual testing we found stars appeared sharp and bright in the middle of the field, while clusters came vibrantly to life. The wide, generous field of view was great for putting regions such as the Double Cluster and Orion's Sword in context. Looking at a bright Moon, we were pleased about the absence of unwanted colour fringing; the air-spaced FPL-53 doublet lens doing a great job. While imaging, we found that the Bahtinov mask provided in the removable dew shield made it a breeze to reach accurate focus. This was also due partly to the ZS61-II's dual-speed rack and pinion focuser, which we liked as it felt very positive and responsive.

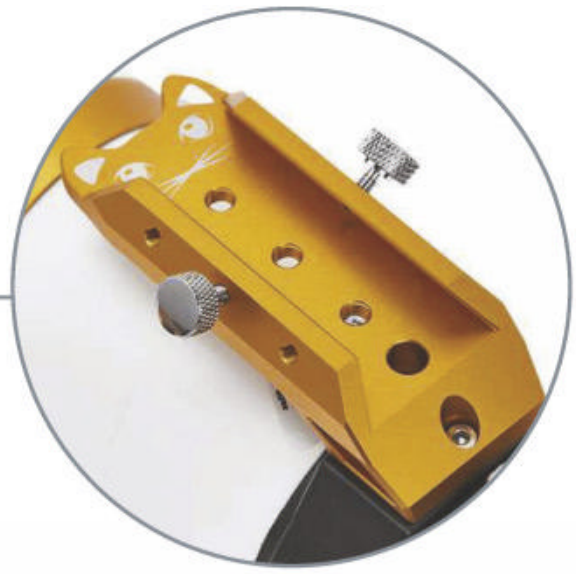
The ZS61-II's focused image circle will illuminate a full-frame DSLR sensor. Using a Canon 6D we noticed a small amount of vignetting – when the brightness of an image falls away towards the extreme corners of the frame – but nothing that couldn't be corrected ▸

High portability

The William Optics ZS61-II is a quality instrument – perfect for wide-field, low power viewing – and it's remarkably portable. With the focuser and dew shield fully retracted, the scope is 25cm in length, 14cm high (from the bottom of the mounting plate to top of the 'Cat Series' saddle handle bar) and 8.5cm wide. It's supplied with a padded carry-case, which is large enough to accommodate optional extras, such as the recommended field-flattener, but not the UniGuide guidescope.

The main ZS61-II telescope – with mounting ring, 'Cat Series' saddle handle bar and mounting plate – weighs 2.15kg, which makes it easy to carry on visits to dark-sky locations. Just add a camera and you have a quality, easy-access imaging setup.

The UniGuide guidescope complements the ZS61-II; it's easy to set up and is portable. It's 25cm in length, 7cm in height and 5.5cm wide, and can be integrated into your usual guiding setup for extended long-exposure imaging.



UniGuide guidescope

Our review kit included a 50mm, f/4, 200mm focal length UniGuide guidescope with a 5.7° field of view. It is designed for a 1.25-inch guide camera barrel secured using a 'Rotolock' adaptor. Focusing is achieved by screwing and unscrewing the front objective lens and locking with a ring.

Mounting ring and saddle handle bar

The ZS61-II's mounting ring has a 'Cat Series' saddle handle bar attached to the top of it. This provides a Vixen-style mounting saddle for attaching auxiliary equipment like the UniGuide guidescope shown here. Two locking thumbscrews secure equipment in the saddle.

Focuser

The ZS61-II has a tension-adjustable, dual-speed rack and pinion focuser, providing smooth movement through its 75mm drawtube range. The focuser accepts 1.25- and 2-inch barrels, securing them with compression rings. A micro-focus knob provides 1/10th speed adjustment for fine-focusing. The drawtube is ruled for repeat focus positioning, while the thermometer is useful to monitor temperature for variations that may affect focus.

Optics

The ZS61-II's objective lens is an air-spaced doublet made from FPL-53 glass, fully multi-coated with Super-Multi Coating. It gives excellent colour correction when tested. The objective's focal length is 360mm, making this an f/5.9 instrument. Field stop baffles are used to eliminate stray light.

FIRST LIGHT

KIT TO ADD

1. William Optics adjustable field flattener for Zenithstar 61

2. William Optics Copper M48 T mount for Canon EOS / Nikon cameras

3. ZWO ASI120MM Mini Monochrome USB 2.0 Camera

▸ with the application of flat frames.

We also noted that optical distortion was present towards the edge of frame. It was by no means terrible, but it would get in the way of serious astrophotography. This can be addressed using an optional field-flattener, such as the William Optics Flat 61A which is designed for use with this scope – although this will set you back an extra £170. At the time of the review the flattener wasn't available.

As a reworked model of the ZS61, the ZS61-II also offers many thoughtful touches, including the Bahtinov focus-assist mask mentioned earlier, an extendable dew shield and the dual-speed rack and pinion focuser. What's new is the mounting cradle, which has a mounting point for an optional guidescope. We tested the William Optics UniGuide guidescope with a 50mm aperture and a 200mm focal length, an optical specification that's not far from the ZS61-II itself. Of course, the UniGuide's optics aren't as refined, nor are its focuser or eyepiece holder.

The UniGuide costs a further £125, but it's worth it if you're serious about auto-guided long-exposure imaging. It's designed to accept a modern, small format guide camera, such as those produced by QHY, ZWO and Altair, with the camera fitting into a 1.25-inch Rotolock adaptor – a 1.25-inch focuser that uses an external rotary screw collar for locking the camera in place. Focusing is achieved by adjusting the front section of the UniGuide and locking it with a ring. The UniGuide is fast at f/4 and delivers a big, wide field of view. Typically, this means you should have a good number of guide stars to choose from.

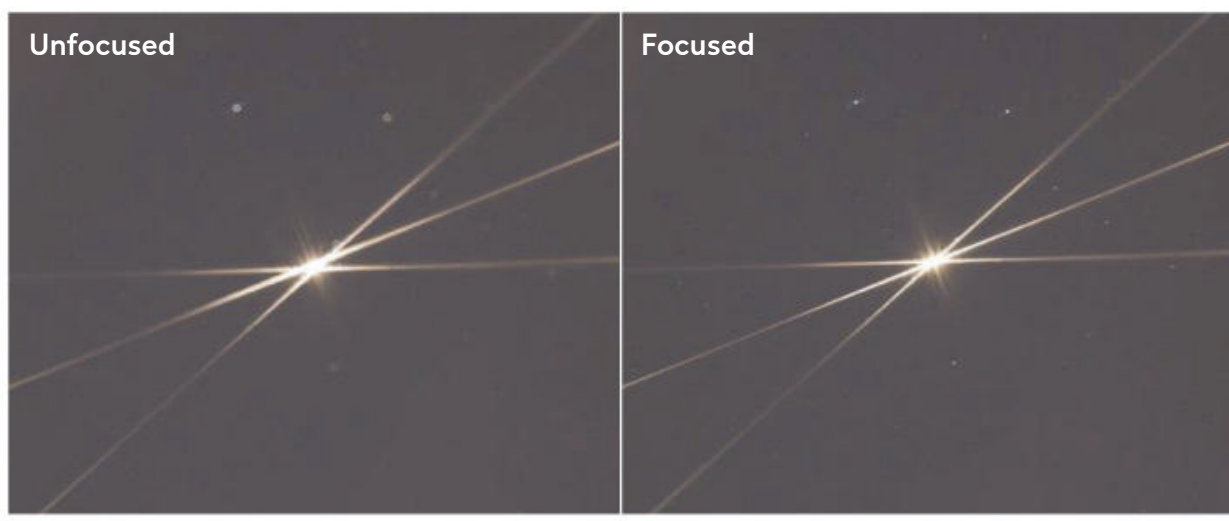
In summary, the ZS61-II is an attractive scope for wide-field viewing and astrophotography. It's highly portable and feels as if it would survive a bump or two, plus it's easy to use and doesn't compromise on functionality. It would also make a high-quality guidescope for a larger instrument.

VERDICT

Build & Design	★★★★½
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★½

Bahtinov mask

The Bahtinov mask inside the dust cap is a nice touch. Concealed behind a screw-off front plate, it's extremely useful for achieving accurate focus by aligning the diffraction pattern it forms on a star to a common cross-over (see below).



▲ The ZS61-II's Bahtinov mask in action with a Canon 6D DSLR, showing how the diffraction spikes it forms on a star are aligned to achieve focus

◂ A high frame-rate capture of the Moon, taken with a ZWO ASI174MM camera attached to the ZS61-II. The image is small but highly detailed

▾ The field of view through the UniGuide guidescope, using a ZWO ASI174MM camera for guiding

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Bresser StarTracker Astronomical Photo Mount Kit

A portable mount and accessories package for wide-field astrophotography

WORDS: CHRIS GRIMMER

VITAL STATS

- **Price** £439
- **Mount** Bresser StarTracker Astronomical Photo Mount PM-100
- **Tripod** Bresser TP-100 DX aluminium tripod with carry bag
- **Payload capacity** 2kg equatorial mode; 5kg altazimuth mode
- **Tracking rates** Star, Sun, Moon, half-speed and time-lapse
- **Power requirements** 4x AA batteries or micro-USB connector
- **Extras** Ball head, polar wedge and polarscope
- **Weight** 3.6kg total kit; 0.6kg tracker only
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

With most astronomy mount manufacturers now offering a portable star tracker option, Bresser's new StarTracker Astronomical Photo Mount Kit joins a busy field. The kit includes a StarTracker Astronomical Photo Mount PM-100, a TP-100 DX tripod, an equatorial wedge, a ball head and a polarscope. If you don't need the full kit – for example, if you already own a good tripod, – the PM-100 mount can be bought separately, but we would definitely recommend the polarscope for alignment purposes. With a weight capacity of 2kg in equatorial mode and a total weight, including tripod and accessories, of just 3.6kg, this mount is aimed at the wide-field photography market and would not be stable enough to take the weight of a small telescope. The photo mount head itself is just 8.6cm x 8.6cm and can fit into a coat pocket for easy transport.

Getting set up

The kit arrived as separate parts, so a small amount of initial assembly was required, but nothing that required any tools, so it only took a few minutes. Instructions were included for each individual part, but the main manual also covers the entire setting up process. The instructions are very thorough and give suggested camera settings for both astrophotography use and time-lapse mode in enough detail to get even a beginner up and running in no time; we were ready to go within five minutes.

We had some initial concerns around the extendable centre column of the tripod – these can sometimes rotate unexpectedly while adjusting a camera and can throw off polar alignment – but the column tightened well and everything felt very solid. Even with the tripod legs extended to their maximum the whole setup felt stable.

Bresser gives approximate maximum exposure lengths in the manual, which covers lenses from 15mm to 100mm, but these will be dependent on polar alignment accuracy. For this review we used a 14mm f/2.8 lens and a 50mm f/2.8 lens, weighing ▸

Easy to control mount

Bresser's StarTracker PM-100 is impressive; lightweight and portable, it runs on four AA batteries (not supplied) or can be powered via a Micro-USB cable, which allows the use of a small power pack such as those designed to charge smartphones.

We found that all the mount settings are controlled by a single control button and easy-to-read LCD screen that is simple to navigate, even in the dark. It enabled us to capture wide, long exposure shots of the Milky Way; with our three-minute exposures proving how capable it was compared with the recommended two-minute exposures. It also performed brilliantly at medium focal lengths (50–100mm), allowing us to capture larger deep-sky objects. We were most impressed by the consistency of its tracking over an imaging session; we left it tracking the constellation of Cygnus for two hours – with exposures of two minutes per shot at 50mm under slightly breezy conditions – and we were able to include every shot when stacking.

Polarscope

The tracker comes with an attachable polarscope that is positioned to allow use when the camera is attached. Polar alignment was simple due to the illuminated reticule; this shows the locations of the Plough and Cassiopeia, allowing us to easily align the polarscope and position Polaris.

Wedge

The polar wedge is small and light, but solid. The initial angle is set by loosening the main adjuster. There are no angle markers, which would have been useful. Fine adjustments are then made with spring-loaded, large thumbscrews that make it easy to centre Polaris.

Tripod

An aluminium photo tripod is included; its telescopic legs have large clamps and there is an extendable centre column. The tripod is reassuringly weighty, so it shouldn't blow or be knocked over. It is easy to carry in the included bag, which has room for the whole tracking mount as well.

SCALE

Ball head

The ball head is smooth and easy to adjust while maintaining resistance to stop the camera flopping around. The camera plate attaches by a screw, which gives a reassuringly solid connection. The only risk is that the screw feels very similar to the angle-adjuster, so care in the dark is required.

LCD screen

The Bresser PM-100 includes an illuminated LCD screen that displays the mount settings. The screen is basic and low resolution, but clearly displays the settings you need. The screen lights up at the press of a button and turns off after a few seconds of inactivity.

A mosaic of the Milky Way taken using the Bresser PM-100 mount, and 4x 60" exposures with a modified Canon 70D DSLR and Samyang 14mm lens at f/2.8

KIT TO ADD

1. The Bresser 100W lithium power supply

2. The Bresser Adventure camera backpack

3. The Explore Scientific Dark-Sky filter with 77mm thread for a photo lens

▸ 1.38kg and 1.1kg respectively with our camera. Indeed, when coupled with our DSLR, a modified Canon 70D with a cropped sensor, we found that each was well within the safe weight range. We also tried out a 150mm lens that gave a combined weight of 1.6kg; despite it being within the suggested weight capacity it felt unstable on the ball head due to the length of the lens.

We put the PM-100 through its paces over a few damp autumn nights while the Milky Way was still visible in the early evening sky. Once set up, we performed a quick polar alignment, which proved easy with the illuminated Bresser polarscope. We started with the 14mm lens attached to our DSLR, testing 30-second exposures and building up to three minutes. Each gave us perfect stars (apart from the usual distortion from this lens). Deciding that our field of view was still not wide enough, we opted to capture a mosaic, which was relatively easy thanks to the supplied ball head adaptor; we were able to move the camera with ease, without any risk of knocking the mount out of its polar alignment. After capturing the Milky Way, we switched the lens for a 50mm one and aimed at the constellation of Cygnus, the Swan. At this focal length Bresser claims that 120-second images are possible. After ensuring our polar alignment was accurate, we discovered we could easily track for 80 seconds without any trailing; it was only when we went higher than this length of exposure that trailing started to become visible.

We loved the compact nature of this kit and found we could pick it up and move it to different locations with ease; if you are needing to hike to a dark and remote site you definitely won't be hindered by the weight. Indeed, the tripod comes with a bag for this very purpose, but even without this the PM-100 mount easily fits in a camera bag alongside your camera and lenses.

As a lightweight tracker that is aimed at wide-field Milky Way photography, this little mount punches well above its weight; the Bresser PM-100 will be a welcome addition to any astrophotographer's kit.

▲ An image of Cygnus, taken using the Bresser PM-100 mount and 58x 120" exposures with a modified Canon 70D DSLR, an Altair Quadband filter and a Sigma 50mm macro lens at f/2.8 and ISO 1600

VERDICT

Assembly	★★★★☆
Build & design	★★★★½
Ease of use	★★★★½
Features	★★★★☆
Tracking accuracy	★★★★★
OVERALL	★★★★½

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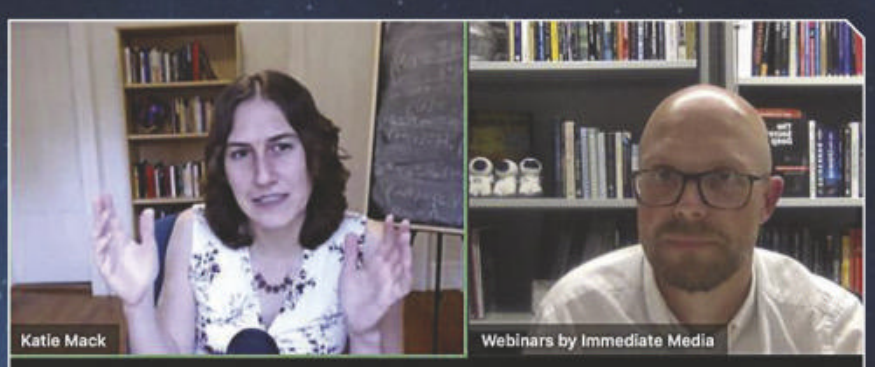

The Whole History of the Universe (Abridged) with Dr Katie Mack. 11 November 2020, 7pm

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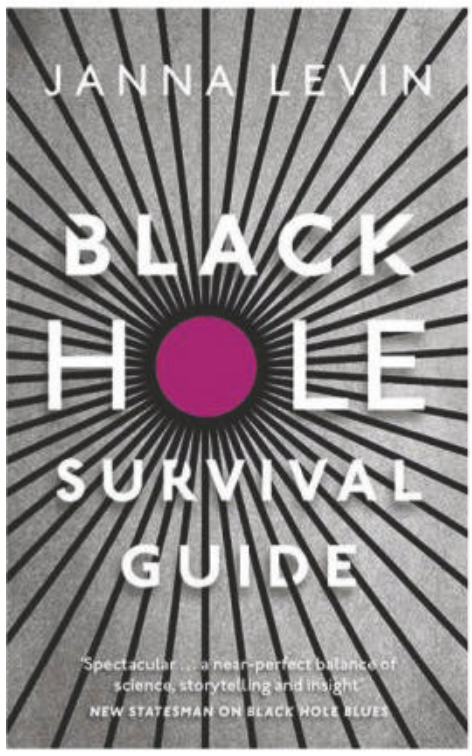


Black Hole Survival Guide

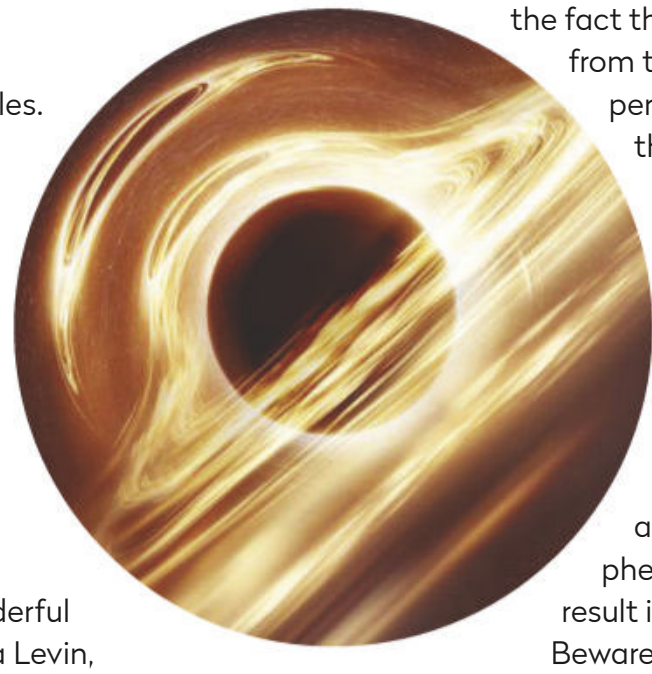
Janna Levin
Bodley Head
£9.99 ● HB

We all love black holes. There's something captivating about these mysterious, scary objects that can rip every particle in our body apart should we get too close. But did you know that black holes, quite literally, "are nothing"? This wonderful statement by Janna Levin, towards the end of the first chapter of *Black Hole Survival Guide*, sets the scene for her new book.

Reading on, we are given all the information we currently know about black holes, as well as some conjecture. Early chapters explore the nature of gravity, time, the event horizon and what it would mean should you cross it. There's a chapter devoted to astrophysics, discussing quasars and the groundbreaking image of a supermassive black hole captured by the Event Horizon Telescope. The chapters of the book, however, which I found most enjoyable, and which made my head hurt a little, explore the quantum mechanical nature of black holes. Here the author explains nicely how black holes can evaporate, the crisis that is the black hole information-loss paradox, and how everything could just be a hologram. She also likens a black hole to a TARDIS: could there be another Universe inside?

Luckily, Janna Levin has a talent for explaining mind-boggling concepts; no prior knowledge is needed and no crazy equations are used. Despite the wealth of content, the book is not long, and the chapters are digestible and provide good breaks to allow you to pause and think. The language is conversational and, in places, rather poetic.

Perhaps the book's greatest draw is the survival guide element. I really enjoyed the fact that this is written from the reader's perspective, setting out the experiences you would have if you are unfortunate enough to fall into a black hole. You do actually get handy tips about how to avoid the extreme astrophysical phenomena that could result in your vaporisation. Beware of black hole jets!



▲ **Staying safe: learn how to avoid being vaporised by a black hole**

SOLARSEVEN/ISTOCK/GETTY IMAGES

This book will really get you thinking, scratching your head, and eventually understanding the nature of black holes. Why don't black holes have hair? Read the *Black Hole Survival Guide* to find out.

★★★★★

***Laura Nuttall** is a senior lecturer in gravitational waves at the University of Portsmouth*

Interview with the author
Janna Levin

Just how big or small can a black hole be?

The biggest we see are about 50 billion times the mass of the Sun, but we don't know any reason they couldn't be as big as the observable Universe. The smallest probably weigh about a few thousandths of a sesame seed. They're actually physically small compared to their heft; if I took something the mass of the Sun, which is 1.5 million km across, and could make it a black hole, it would be 6km across and fit into New York's Central Park.

What would happen if you were swallowed by one?

If you choose a big enough black hole, it shouldn't be unpleasant at first. The little bundle of light that you emitted as you crossed the event horizon could get stuck there. You would perceive it as travelling at the speed of light because you can't sit still in the event horizon; you fall through. Next, you'd be flayed and shredded; space time is converging strongly towards this point, so it's like a storm in space time that you have created by being there. You would be ripped apart and turned into your subatomic particles.

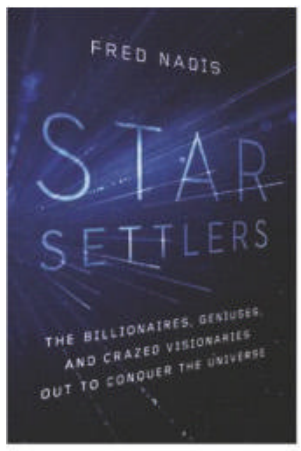
Which forms first: a galaxy or its central supermassive black hole?

I don't think we fully know. Black holes that massive don't form directly from stellar collapse, we don't think, since they're millions or billions of times the mass of our Sun. But you can make black holes 80 or 150 times the Sun's mass by colliding black holes, and if you have enough collisions you get a really big one. If it happens like that, maybe the galaxy was here first.

***Janna Levin** is a science author and the Claire Tow Professor of Physics and Astronomy at Barnard College of Columbia University*

Star Settlers

Fred Nadis
Pegasus Books
£20 ● HB



Where do big ideas come from? How does one go from thinking about colonising Mars to making such an endeavour a reality? Who conceives of space hotels? What sort of people take ideas that appear to be science fiction and turn them in to science fact? *Star Settlers* certainly attempts to answer some of these questions and more on the topic of human space exploration.

From an extensive catalogue of interview and archive material, author Fred Nadis explores the mindset and motivations of leading visionaries, fans and scientists of the space sector past and present. This includes Konstantin Tsiolkovsky, the rocket scientist and pioneer of astronautic theory, and John P Allen, the designer of the two-year Biosphere 2 mission, as well as billionaire space oligarchs such as Elon Musk, Jeff Bezos and Robert Bigelow.

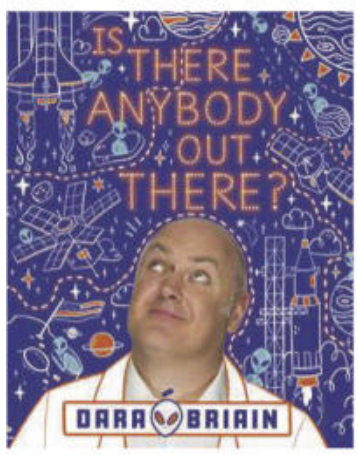
What is particularly appealing about this latest work from the award-winning writer Kardis is his ability to share well-documented, existing chronicles of space from a new perspective: the human perspective. Whether it's Wernher Von Braun, Bigelow, Musk or Lowell, he capably places these central figures at the core of each chapter, recounting the facts through the lens of the individual and the world they inhabit. This reveals enemies and allies, obsession, tenacity and determination – as well as the personal cost of following a dream.

While the prose meanders a little at times, it is a well-written, well-researched and entertaining read and certainly adds a glimpse of the cultural cauldron in which the history of spaceflight continues to bubble. ★★★★☆

***Niamh Shaw** is an engineer, speaker and space science communicator*

Is There Anybody Out There?

Dara Ó Briain
Scholastic
£12.99 ● HB



Dara Ó Briain is perhaps best known as the comedian who chairs TV's *Mock The Week*, but astronomers remember him also as the co-presenter of the BBC's *Stargazing Live*. He is also a qualified scientist, having studied mathematics and theoretical physics at university.

Is There Anybody Out There? is the latest in a series teaching younger children about science: this compact volume looks at the prospect of alien life.

We learn how the notion of aliens has fascinated humankind throughout history, with imagined canals on the Red Planet and visits by flying saucers. Scientific attempts to answer the title question include the famous Fermi Paradox and Drake Equation, as well as experiments listening for messages using radio telescopes.

A potted description of how the Universe, stars and planets formed is followed by a look at how life begins and evolves, and why Earth is a particularly good host for it. Ó Briain ponders whether similar life might exist elsewhere in the Solar System, or beyond. If it does, how can we visit or communicate with it?

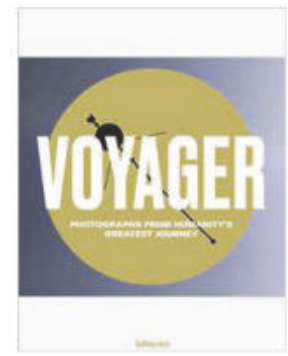
As you might expect, the style is very off-beat. Each page is presented in a variety of typefaces and font sizes to appeal to younger readers, which may induce a migraine in older readers. The text is heavily peppered with jokes, and you can almost imagine Ó Briain delivering it as a stand-up routine in *Live at the Apollo*. But this is a topic that fires the imagination, and if the light humour helps teach a bit of science, then that's great too. ★★★★☆

***Paul Sutherland** is a science journalist and space writer*

Voyager

Jens Bezemer, Joel Meter et al
teNeues
£45 ● HB

PACKED WITH IMAGES



Put together by five seasoned photographers and prefaced by Voyager Imaging Team member Garry Hunt, this large-format volume will blow the socks off any interested coffee-table reader. Its scope becomes readily apparent in its inspirational quotes, from Carl Sagan's "Somewhere, something incredible is waiting to be known", to Carolyn Porco's assertion that exploration is about human longing to know ourselves and why we are here.

The authors tell the history of Voyager, our first foray to all four giant planets – Jupiter, Saturn, Uranus and Neptune – which revealed their multitude of moons and rings, their atmospheres and magnetospheres, and the clues they may reveal about our origins. We meet the mathematical, engineering and scientific geniuses who identified the once-in-three-lifetimes fluke that permitted us to visit these previously unseen worlds through a clever mix of celestial mechanics and good fortune.

The authors juxtapose the minutiae of building the spacecraft, operating the deep-space communications equipment and guiding the Voyagers across billions of miles of uncharted emptiness with captivating tales of our ancestors' understanding (and misunderstanding) of these tiny points of light in the night sky, which they dubbed 'planets'.

But the real beauty of this book is its gorgeous assemblage of remastered photographs. There are pictures here that I have never seen before. And those I had seen were brought so wondrously and vividly to life that they left me open-mouthed in awe. *Voyager* is like a trip to a never-before-seen land, where each turn in the road reveals a new panorama. In this book, each turn of the page does nothing less. ★★★★★

***Ben Evans** is the author of several books on human spaceflight and is a science and astronomy writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Bresser 5x APO Barlow lens

Price £43 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

This Barlow lens extends the focal length of your optical system by five times, allowing you to achieve high magnifications without having to use uncomfortably short eyepieces.

2 Noteworthy Constellations A5 notebook set

Price £4.99 • **Supplier** Create and Craft
www.createandcraft.com

Record your thoughts in style with this set of three notebooks decorated with stylised star charts and constellations. One of the trio is filled with squared paper, making it great to use as an observing log book, while the other notebooks are lined and plain.

3 Hubble 1,000-piece puzzle

Price £14.99 • **Supplier** Thumbs up • **www.thumbsup.com**

Study deep-sky objects even when it's cloudy out with this 1,000-piece puzzle. The three available designs depict a different nebulae image, taken by NASA's Hubble Space Telescope – any of which will provide a challenge even for jigsaw experts.

4 Celestron FireCel+ 5200

Price £19.95 • **Supplier** Tring Astro
Tel 01442 822997 • **www.tringastro.co.uk**

Cut down the amount of kit you have to cart around during observing with this device, which works as a torch, handwarmer and USB charger. The torch comes with five modes and both red and white light LEDs.

5 Teleskop Service padded carrying bag

Price €102 • **Supplier** Teleskop-Express
Tel +49 (0) 8999 228 750 • **www.teleskop-express.de**

Keep your scope protected during travel or storage with this padded, weather-proof carry bag. The bag is 65cm long and 34cm in diameter, making it a great fit for reflectors around 23cm in diameter, though it can be modified for smaller scopes with more padding.

6 Deep-Sky Planner 8

Price £71 • **Supplier** Knightware
https://knightware.biz

Whether you're a visual observer or an imager, this software will help you plan and log your observing sessions and get the most out of your time under the stars. The database now includes 1.6 million objects.

Ezzy Pearson interviews Lisa Upton

Q&A WITH A SOLAR CYCLE PREDICTOR

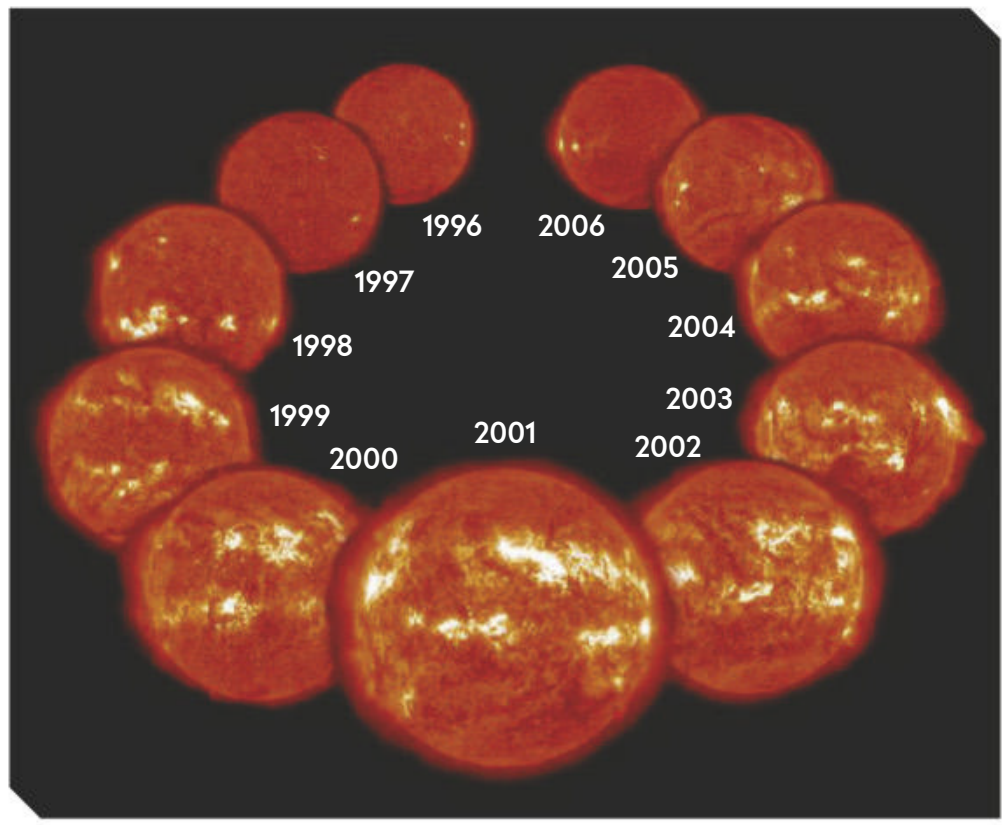
As the Sun reawakens from the low point in its 11-year pattern of activity, a group of scientists has predicted what the new solar cycle will be like

What is the solar cycle?
It's the cycle of sunspots that is driven by the Sun's evolving magnetic field. They appear at the beginning of a solar cycle, starting at high latitudes with very few of them. As the solar cycle progresses, they become much more frequent and move to lower latitudes, peaking at a solar maximum; then there's a declining phase. The solar cycle has a period of about 11 years and we've got records of the last 24 cycles.

You're a member of the Solar Cycle 25 Prediction Panel – what is that?
Every solar cycle there is an international organisation that convenes a group of experts to make predictions about the next solar cycle. Back in 2019 we asked solar scientists to submit their predictions to us and then we used them to come up with a consensus as to how we thought the next solar cycle would be. The predictions are also for those outside the solar community; as the more sunspots there are, the more solar flares, coronal mass ejections and coronal holes there are and these kinds of activity can impact us here on Earth. We're mostly protected by Earth's magnetic field, but astronauts or satellites in space can be very much impacted by these solar storms.

What were your predictions?
We're officially charged with predicting the solar minimum, the maximum and the amplitude, but we also like to estimate some other things like how many flares there might be. We predicted that solar minimum would occur in April 2020, plus or minus six months. It took a while to say for sure when the solar minimum was – as we take a 13-month average of sunspot numbers – so we don't know we've passed the minimum until at least six months afterwards. In the last month or two we've been able to look back and see that minimum occurred in December 2019.

We also predicted the solar maximum to be in July 2025, plus or minus six months, but because the minimum shifted earlier it might be closer to the beginning of 2025. That said, the timing of the maximum is a little bit less clear. In Solar Cycle 24, for example, there were two pronounced peaks two years apart. Is the maximum timed with the first peak, the second peak or somewhere in the middle? So it's a rough estimate.



NASA

▲ Cycle of the Sun: images of the Sun's disc taken during Solar Cycle 23 reveal its changes from solar minimum (top left) to maximum and back again (top right)

How did you make those predictions?
There are three different ways. First, there are numerical methods, where you look at the historical records of solar cycles and see if you can use statistical analysis to guess what the next cycle will be. The second set of approaches are more physics-based; these look at the science of what's going on in the Sun and then use that knowledge to try and make predictions. This includes looking at the geomagnetic activity here on Earth or the strength of the Sun's polar magnetic field. The final option encompasses anything that wouldn't fit into the other categories. You get all kinds of things – like people looking at the orbit of Jupiter; there's been very little evidence to substantiate that, but there are all kinds of ideas. Overwhelmingly though, we find the physics-based methods have been more effective.

How is Solar Cycle 25 looking?
It's looking like it's going to be right on par with Solar Cycle 24, which was the weakest cycle we've had in the last 100 years. But little cycles happen and it's not so small that we're worried the Sun is dying or anything. One of the things that will be interesting to see is if, after 25 the cycles, it starts to ramp up again.

Can you make any predictions for future cycles?
We really are very limited and can only predict the next cycle when we're close to the end of the previous one. We're not going to be able to say anything about Solar Cycle 26 for another eight or nine years. That's a big motivator for the kind of science and research that we're doing, but whether there's a fundamental limit to how far you can predict future solar activity remains an open question.

Dr Lisa Upton works for the Space Systems Research Corporation and is a co-chair of the Solar Cycle 25 Prediction Panel

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Look out for a meeting of six planets in the evening sky, and enjoy a view of Orion's brightest star Rigel

When to use this chart

1 Jan at 00:00 AEDT (13:00 UT)
15 Jan at 23:00 AEDT (12:00 UT)
31 Jan at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JANUARY HIGHLIGHTS

Following the Great Conjunction of Jupiter and Saturn, the gas giants drop into the evening twilight. Mercury enters the evening sky, passing them as they prepare to exit; on the 11th it has its closest approach to Jupiter, only 1.5° away. Although low in the twilight glow, the planets should be visible a few degrees above the horizon, 30 minutes after sunset. On the 14th, the thin crescent Moon joins in, only 1.5° from Mercury with Jupiter 4° below.

STARS AND CONSTELLATIONS

One of the brightest Mira-type variable stars, S Carinae, HD 88366, is located near the Eta (η) Carinae Nebula. Its brightness ranges from around sixth to ninth magnitude over a period of 149 days and is easily followed with binoculars. The star is expected to be near a minimum in January rising to a maximum in April, the best time to follow Carinae in the evening sky. Locator information can be obtained from the American Association of Variable Star Observers at **www.avso.org**.

THE PLANETS

Observe six planets in the evening sky! As mentioned above, Jupiter and Saturn are in the western twilight sky and can be caught early in the month. Mercury has a generally poor evening apparition in January, low in the solar glow and best around the week of the 20th. Neptune should be the next, departing around 22:00 mid-month. The evening feast concludes with Mars and Uranus, setting around midnight mid-month. Meanwhile, Venus remains low in the eastern dawn sky.

DEEP-SKY OBJECTS

The brilliant star Rigel (Beta (β) Orionis), along with Betelgeuse (Alpha (α) Orionis), shines out in the constellation of Orion, the Hunter. As well as being the 7th brightest star, Rigel is also a double, a pair of blue stars of mag. +0.2 and +6.8, separated by 9.5 arcseconds.

Next up, an unusual object in neighbouring Monoceros. Almost 11° east of Betelgeuse, lies the nebula complex of NGC 2264. Only 1° south is Hubble's Variable Nebula – NGC 2261 (RA 6h 39.2m, dec. +8° 44'). It's only 2 arcminutes long and resembles a comet. A faint star, R Monocerotis, forms the nucleus with the nebulae fanning out northwards – the tail. Over the years its brightness and visible size has changed, thought to be due to a combination of R Monocerotis being variable and shifting clouds casting shadows on the nebula.

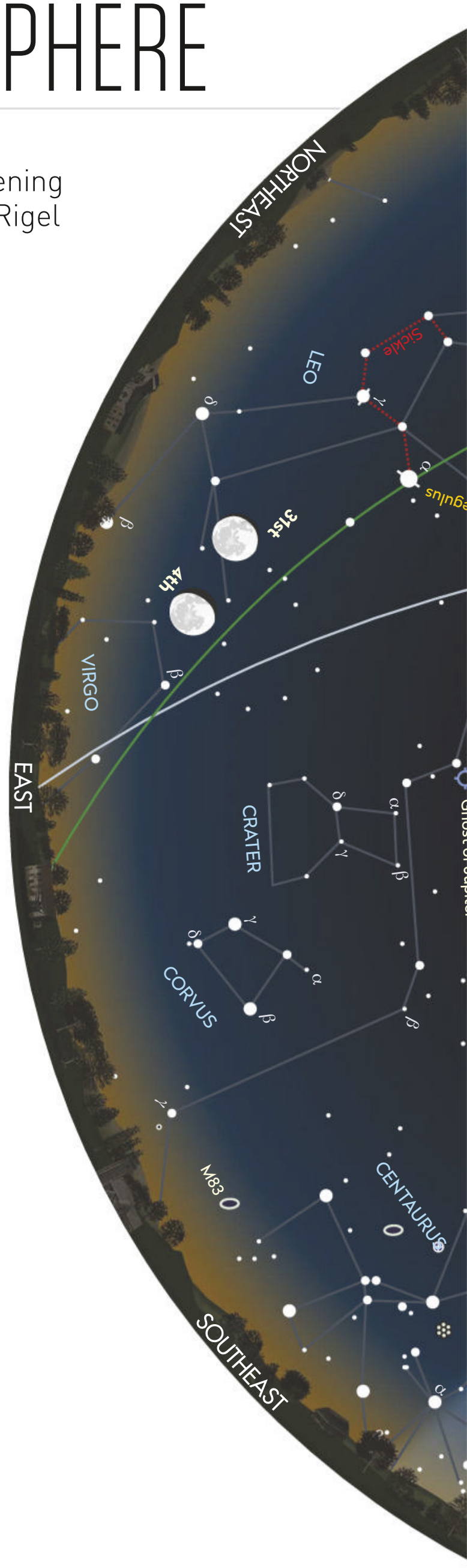
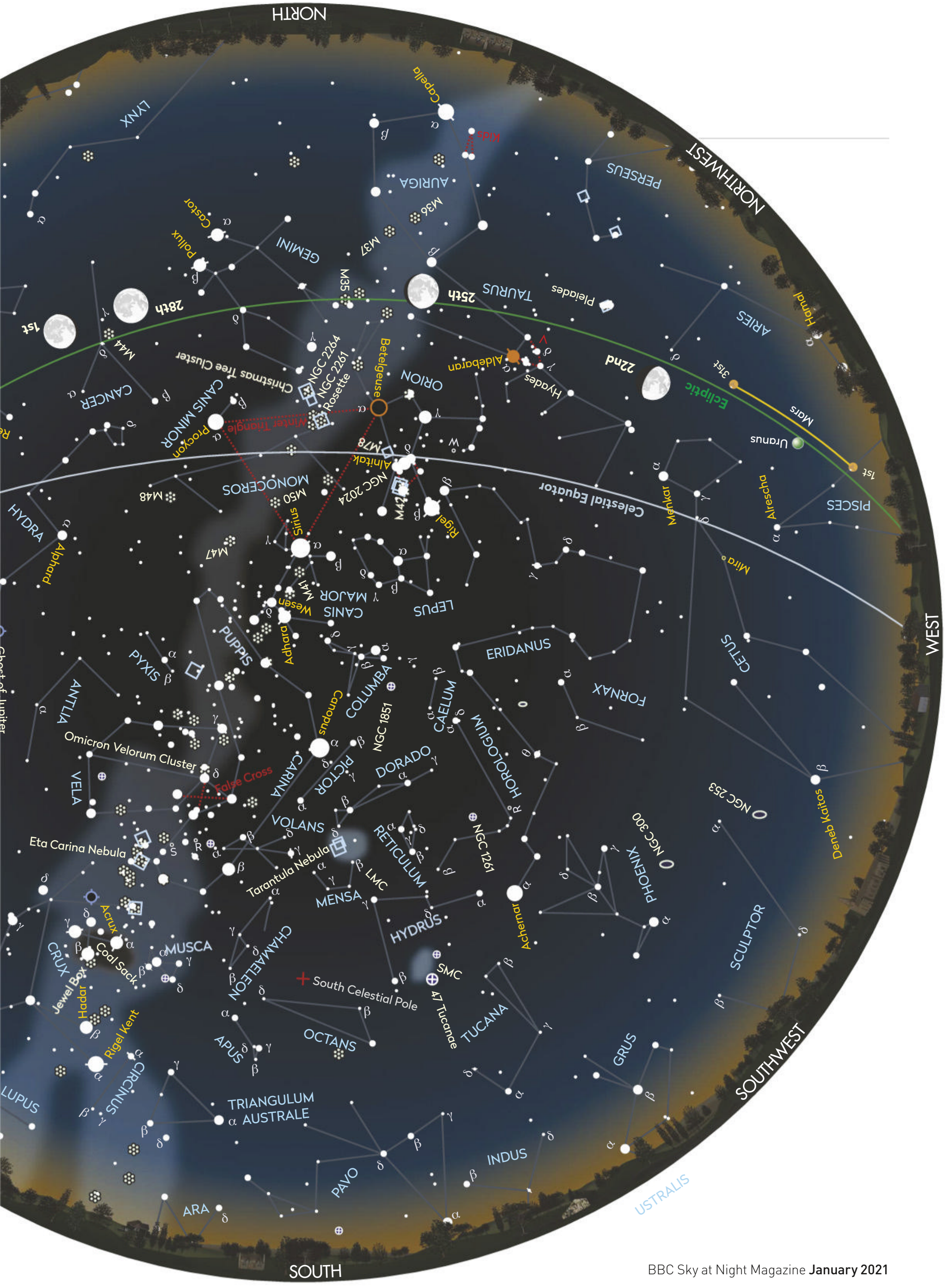


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LYNX
Capella
Kids
AURIGA
M36
M37
PERSEUS
Castor
Pollux
GEMINI
M35
28th
25th
TAURUS
Pleiades
ARIES
Hamal
1st
M44
Christmas Tree Cluster
NGC 2264
NGC 2261
Rosette
Betelgeuse
Aldebaran
Hyades
22nd
Ecliptic
31st
Mars
CANCER
CANIS MINOR
Procyon
Winter Triangle
ORION
M78
Alnitak
Uranus
1st
NGC 2024
M42
Celestial Equator
Menkar
Alrescha
PISCES
M48
MONOCEROS
M50
Sirius
Rigel
Mira
HYDRA
Alphard
M47
M41
Wezen
CANIS MAJOR
LEPUS
PUPPIS
Adhara
PYXIS
ANTLIA
Omicron Velorum Cluster
False Cross
VELA
Canopus
COLUMBA
NGC 1851
CARINA
PICTOR
DORADO
CAELUM
HOROLOGIUM
ERIDANUS
FORNAX
CETUS
NGC 253
Deneb Kaitos
VOLANS
Eta Carina Nebula
Tarantula Nebula
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